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QUABBIN WATERSHED:
MDC LAND MANAGEMENT PLAN
1995 - 2004

Commonwealth of Massachusetts

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Executive Summary

The 58,000 acres of undeveloped, MDC-controlled land surrounding Quabbin Reservoir are its most valuable asset. This 10-year Quabbin Watershed Land Management Plan sets out policies, goals, and methods for managing these lands with the express purpose of protecting the public water supply. In addition, the plan describes MDC's land acquisition plan to increase the undeveloped buffer around the reservoir, as well as plans to protect wildlife and cultural resources through specific management practices.

The primary focus of MDC's land management plans is to provide the best possible cover throughout the watersheds for protecting tributary water quality. The preponderance of forest cover surrounding Quabbin Reservoir is reflected in this plan's emphasis on forest management activities. The most important goal for this plan is to **maintain the functioning of this watershed protection forest**, in both the short and long terms.

Short-Term (10 years): Inadequate regeneration has been determined to be the greatest deficiency of the current MDC forest surrounding Quabbin. Therefore, the most important short-term objective of this plan is to manage the forest and wildlife resources to **foster tree regeneration across MDC-controlled watershed land**.

Long-Term (60 years): The second most important objective of this plan is to begin to **establish the diverse, stable, multi-layered forest** that will improve watershed protection in the long-term. This type of cover has been determined to be optimal with regard to watershed protection.

KEY OBJECTIVES OF PLAN:

Short-Term (10 years)

• Regeneration serves to anchor soils following disturbances, resists damage from many disturbances (due to its size and density), assimilates nutrients more rapidly than older vegetation, and shortens recovery times for reestablishing forests following disturbances. To compensate for regeneration deficiencies, a conservative, non-intensive silvicultural approach to fostering regeneration is specifically outlined, whereby preparatory and release cuttings, as well as limited enrichment planting, will establish regeneration and new forest layers. These activities will occur within approximately 15,000 acres during this management period. Specific map locations of planned silviculture are provided in a supporting appendix. Specific "best management practices" are outlined for forest management, road maintenance and wildlife management.

• The establishment and survival of forest regeneration on much of the Reservation is dependent upon continued control over deer browsing impacts. Deer browsing impacts will be maintained at low levels, compatible with the development of new forest layers.

Long-Term (60 years)

• Long range plans to continue non-intensive silviculture are outlined as the best way to meet the long-range objective of a diverse, stable, multi-layered forest within the next 60 years.

• A method for evaluating the relative importance to water supply of each of the many "sub-basins" at Quabbin is outlined. This will be used to list priorities for watershed protection activities such as forest management, land acquisition, and wildlife impact control. This approach will also identify "secondary use" areas where priorities other than water suply could be addressed.

• A specific program of research aimed at assisting watershed management is outlined, including three projects to which MDC has committed $50,000 in fiscal year 1995. Watershed management research will be used to annually revise and update this plan.

• A Science and Technical Advisory Committee is set up with the expertise to assist MDC in revising this plan annually to meet long-term goals and to advise MDC in developing and implementing a research program to assist watershed management.

The following is a more detailed summary of the seven sections of the plan including background information, policies, and program descriptions.

I. Introduction, Mandates and Statement of Mission

*Contents: This section presents the legislative mandates, agency mission statements, and other foundations for MDC's land management program, as well as a general overview of the plan.

* Key Points: Two key statutes provide the primary legislative mandates for MDC's land management activities. Chapter 372 (Acts of 1984) established the Division of Watershed Management and directed it to "*...utilize and conserve...water and other natural resources in order to protect, preserve and enhance the environment of the commonwealth and to assure the availability of pure water for future generations.*" In addition, Chapter 737 (Acts of 1972) included far-reaching directives and restrictions on the types and extent of both public and management activities permitted on Quabbin Reservation.

Both statutes set forth clear authority for the active management of the watershed and its natural resources. Chapter 372 directed the DWM to periodically prepare watershed management plans that shall provide for "*...forestry, water yield enhancement and recreational activities.*"

II. Description of MDC Watershed Resources

*Contents: This section gives an overview of the natural and cultural resources contained on Quabbin watershed lands.

*Key Points: The MDC controls approximately 68% of the 120,000 acres in the Quabbin watershed, including land and water. Privately-owned forest land comprises 24.1% (28,846 acres) of the watershed. Of the land controlled by the MDC, approximately 54,000 acres are forested, while the 3,855 acres of open lands include approximately 2,270 acres of open wetlands, 175 acres of utility right of ways, 690 acres in roadways, and 720 acres in fields.

Quabbin soils are grouped into five types with approximately 10% excessively well-drained, 34% well-drained thin, 27% well-drained thick, 19% moderately well-drained and 8% poorly drained.

The East Branch of the Swift River is the largest sub-watershed of the Quabbin, draining 43.7 of the total 150 square miles of the watershed. The average precipitation yield to the reservoir from the entire watershed is approximately 50%.

The present forest overstory is in two distinct ages - the majority is greater than 90 years old and a smaller area is approximately 55 years old. Within the managed forest (approximately 48,000 acres), forest types are 2/3 hardwoods and 1/3 softwoods, with 48% in oak types and 21% in white pine types. MDC silvicultural practices have removed an estimated 10-30% of the annual volume growth of the managed forest over the past decade. Analysis of regeneration data collected since 1989 shows consistently that although seedling establishment of all local species is adequate nearly everywhere, the height development of these seedlings has been impaired in areas where the populations of white-tailed deer regularly exceed the levels found in areas that are hunted.

Wildlife on the Quabbin is abundant and varied, and includes at least 27 species on the "special concern" list of the Natural Heritage and Endangered Species Program, including the Common Loon and the Bald Eagle. A variety of formal and informal surveys track the presence of both common and uncommon species.

Cultural resources on the Quabbin include both historic and prehistoric sites. The Massachusetts Historical Society maintains records on more than seventy prehistoric sites on the Quabbin watershed. More than 1000 buildings were removed from the watershed at the time of the building of the reservoir, leaving behind many intact foundations and miles of stone walls of historic interest.

III. Research-based Principles Guiding Watershed Management

*Contents: This section identifies principles of watershed management that drive management goals and objectives for the Quabbin watershed lands. These principles were distilled from the comprehensive literature review included in the SUPPORTING APPENDICES for this plan, which summarizes the findings from approximately 350 watershed, forestry, and wildlife management papers that were reviewed by Division staff. Principles are identified in the areas of Watershed Protection, Water Yields, Watershed Forest Management, Air Pollution Impacts, and Wildlife Impacts.

*Key Points: The central principle of Watershed Protection is the importance of maintaining forested, undeveloped cover across most of the watershed. Control of human activities, maintenance of roads (to prevent erosion while allowing access), and careful attention to riparian zones and wetlands follow as important Watershed Protection principles.

While some components of Water Yields are not controllable (e.g., precipitation, soil characteristics, topography), changes in vegetative cover, through management or natural disturbance, can have significant effects. Generally, as forest cover increases, water yields decrease.

Watershed Forest Management can be conducted with minimal negative impacts to water quality, through careful adherence to Best Management Practices for harvesting and road maintenance. Forest management can deliberately restructure the forest so that it is better able to resist, and recover from, the impacts of severe natural disturbances. By maintaining a component of young forest throughout the

watershed, this restructuring can provide both rapid recovery from disturbance and aggressive uptake of nutrients.

Among the principles cited under the topic of Air Pollution is that forests function as "sinks" for airborne pollutants, mitigating their impacts. While this may benefit water quality protection, tree survival is affected by air pollution damage. Maintaining diverse and vigorous forests may mitigate this damage. Nitrogen saturation (in which nitrogen inputs from air pollutants exceed the assimilative capacity of the system) is of increasing concern in watershed forests, since it can lead to nitrate losses to streams. Again, forests that are actively accumulating biomass can mitigate these effects through increased assimilation.

Wildlife Impacts on water quality conditions can occur either directly or through modifications of watershed cover conditions. In turn, modifications of habitat conditions, as well as changes in mortality factors, can impact wildlife populations.

IV. MDC Watershed Management Goals

*Contents: Based upon the principles distilled from the literature and local research, the experiences of MDC staff in managing watersheds, and the mandates from the laws and regulations that govern MDC land management, this section details MDC goals for overall Watershed Management, Water Quality and Yields, Land Protection, Forest Management, Wildlife Management, and Cultural Resource Protection.

*Key Points: The Division's overall Watershed Management goals, for land management, are to:

- PROVIDE THE BEST POSSIBLE COVER THROUGHOUT THE WATERSHED FOR PROTECTING RESERVOIR WATER QUALITY; AND
- MINIMIZE OR MITIGATE BOTH POINT AND NON-POINT SOURCES OF WATER POLLUTION.

Division goals for Water Quality and Yields are to:

- CONTINUALLY MEET THE MASSACHUSETTS SURFACE WATER QUALITY STANDARDS FOR CLASS A WATERS AND REGULATIONS FOR SOURCE WATER QUALITY RESULTING FROM THE U.S. E.P.A. SAFE DRINKING WATER ACT; AND
- MINIMIZE THE LONG-TERM CUMULATIVE EXPORT OF NUTRIENTS AND SEDIMENTS TO THE RESERVOIR; AND
- PREVENT DECLINES IN WATER YIELDS; IN ORDER TO
- PROVIDE A SAFE AND SUFFICIENT SUPPLY OF WATER FOR PRESENT AND FUTURE GENERATIONS.

Division goals for Land Protection are to:

- LIMIT LAND USES ON THE WATERSHED TO THOSE THAT DO NOT THREATEN WATER QUALITY; AND

- PROVIDE CONTROL OVER NON-FOREST LAND USE (E.G., ROADS), THE EFFECTS OF NATURAL EVENTS (E.G., FIRE), AND HUMAN ACTIVITIES THAT THREATEN WATER OR OTHER NATURAL RESOURCES.

Division goals for Forest Management are to:

- PROVIDE A DIVERSE, VIGOROUS FOREST COVER ACROSS THE VAST MAJORITY OF THE WATERSHED;

- MAINTAIN FOREST COVER THAT BALANCES ACTIVE GROWTH AND NUTRIENT ASSIMILATION, DENSE FILTRATION, TEMPERATURE REGULATION, AND ACTIVE REPRODUCTION;

- RETAIN THIS FOREST COVER BY EXPEDIENTLY RE-ESTABLISHING AND MAINTAINING ADEQUATE FOREST REGENERATION ACROSS MDC QUABBIN LANDS;

- ENHANCE AND MAINTAIN THE ABILITY OF THE WATERSHED FOREST TO BOTH RESIST AND RECOVER FROM DISTURBANCE;

- PREVENT EROSION OF SEDIMENTS AND NUTRIENTS FROM THE WATERSHED FOREST, AND PROVIDE FOR ACTIVE ASSIMILATION OF AVAILABLE NUTRIENTS;

- LIMIT THE EFFECTS OF HUMAN-CAUSED AIR POLLUTION BY PROVIDING COVER THAT FILTERS AND/OR BUFFERS POLLUTANTS;

- DEVELOP A LOW-MAINTENANCE WATERSHED FOREST, WHICH PROVIDES LONG-TERM WATER QUALITY PROTECTION WITH MINIMAL INTERVENTION;

- CONDUCT FOREST MANAGEMENT ACTIVITIES SUCH THAT THE RESULTING BENEFITS OUTWEIGH ANY POTENTIAL NEGATIVE IMPACTS;

- SALVAGE DEAD AND DOWNED MATERIAL IN AREAS WHERE THIS SALVAGE WILL SIGNIFICANTLY REDUCE THE THREATS OF FIRE OR NUTRIENT TRANSPORT, AND LIMIT THE NEED FOR SALVAGE THROUGH DELIBERATE MANAGEMENT PRACTICES AIMED AT REDUCING THE LIKELIHOOD OF DAMAGE.

Division goals for Wildlife management are to:

- MITIGATE POTENTIALLY ADVERSE IMPACTS OF WILDLIFE ON WATER QUALITY, INFRASTRUCTURE, AND OTHER WATERSHED RESOURCES;

- PROTECT UNCOMMON, RARE, AND OTHERWISE SIGNIFICANT WILDLIFE SPECIES AND HABITATS WHEREVER THEY EXIST ON MDC LANDS;

- ASSESS AND MITIGATE IMPACTS OF WATERSHED MANAGEMENT ACTIVITIES ON WILDLIFE THROUGH A PROCESS OF NOTIFICATION, SITE VISITS, REVIEW OF RECORDS AND LITERATURE, AND RECOMMENDATIONS TO APPROPRIATE MANAGEMENT STAFF; AND

- ACTIVELY MANAGE FOR SELECTED WILDLIFE SPECIES THAT ARE CONSIDERED TO BE UNCOMMON, RARE, OR UNIQUE ON A REGIONAL OR STATE-WIDE BASIS.

Division goals for Cultural Resource Protection are to:

- IDENTIFY SIGNIFICANT CULTURAL RESOURCES ON WATERSHED LANDS; AND
- PREVENT DEGRADATION OF CULTURAL SITES AND RESOURCES.

V. 1995-2004 Management Plan Objectives and Methods

*Contents: This section details the management objectives developed by the MDC to meet the goals specified in the previous section, and provides detail on the methods chosen to accomplish these objectives, in the areas of Land Protection, Forest Management, Wildlife Management, and Protection of Cultural Resources.

In the Forest Management section, three alternatives for forest management on the watershed are compared, including: active management with the principal goal of enhancing water yields, active management with the principal goal of water quality protection through the maintenance of stable forest cover, and natural management with the principal goal of water quality protection through limited human intervention. This section then describes the selection of Alternative #2 and outlines the objectives for implementing this Alternative.

Section V also includes a review of the proposed "cumulative sub-basin analysis", which the Division will initiate during this management period in order to refine the location and extent of its management priorities. The final topic covered is the development of a separate management plan for Quabbin Park.

Land Protection Activities:

Land Acquisition

*Contents: MDC has had an active land acquisition program at Quabbin. Over the past seven years, 2,160 acres of land within the Quabbin watershed have been purchased. This section outlines why and where MDC will continue to acquire private watershed lands.

*Key Points: At Quabbin, a total of 2.85 million dollars is recommended to be spent over the next 3-5 years on acquiring approximately 1,450 acres of key private lands, utilizing monies set aside in the Watershed Protection Act of 1992. Wherever necessary, MDC will continue to install gates across roads acquired in this program to limit vehicle access and dumping.

Technical Assistance to Private Forestland Owners

*Contents: This section outlines proposed plans to encourage private forestland owners on the watershed to maintain their land in forest cover.

*Key Points: Nearly 29,000 acres within the Quabbin watershed are "unprotected", privately-owned forestland. MDC has established a Demonstration Forest on 200 acres of forest adjacent to the Quabbin Visitor Center, which encourages landowners with many different objectives to become active stewards and to keep their land in forest cover. MDC is investigating the expenditure of funds to help private forestland owners on the watersheds to complete forest management plans that, in turn, qualify them for federal cost-share assistance to conduct management activities that are desirable from a watershed protection standpoint.

Policing

*Contents: This section describes the general approach to assuring adequate police protection in order to prevent activities that would degrade water quality.

*Key Points: The priority justifications for policing the watershed are to protect against public access violations, dumping, encroachments, and permit non-compliance. In order to assure that adequate policing occurs, MDC will meet regularly with the Mass. State Police at Quabbin to set priorities for patrols.

Fire Protection

*Contents: The improvements that MDC has made in the past five years in this area are outlined.

*Key Points: Fires can cause serious impacts to the watershed. Most fires have been caused by the visiting public, so recommendations include stricter enforcement of the prohibition against the landing of fishing boats, and elimination of public access during extremely dry periods. Details are given for improving the Division's prevention and suppression of fires. Recommendations are made to update MDC's fire protection system including the purchase of new equipment and the training and coordination of staff.

Access Roads

*Contents: The improvements that MDC has made in the past five years in upgrading access and erosion control along its access roads are outlined.

*Key Points: A specific program is outlined to maintain access roads in good condition and to upgrade 48 miles of the existing road system. The need for approximately 8,000 cubic yards of gravel per year over the ten year period, in order to complete access roads improvements, is outlined. The areas where this gravel will be extracted are detailed.

Areas with Special Management Restrictions

*Contents: In past management plans, MDC has described areas where silviculture would not occur. This section updates past definitions of Areas with Special Management Restrictions and lists areas currently restricted.

*Key Points: Approximately 10,000 acres of MDC Quabbin lands have been classified as Areas with Special Management Restrictions. These areas include large blocks of land such as the 3,712 acres of reservoir islands and two blocks in excess of 1,000 acres each in Quabbin Park and adjacent to Pottapaug Pond. They also include 1,712 acres of steep slopes and 2,272 acres of wetlands. In addition, many small areas have been included, representing sensitive resources and buffers around historic and rare wildlife habitats.

Within this management period (1995-2004), no specific changes have been proposed for management of past "protection zones" with the exception of limited (approximately 200 acres) application of non-harvest silviculture in shoreline red pine plantations.

Forest Management Activities:

Description of Forest Management Approach for Ten Years (1995-2004)

*Contents: This section opens with a description of three forest management alternatives that were considered in the development of this plan: Alternative #1, active management with the goal of increasing water yields; Alternative #2, active management with the goal of long-term water quality protection; and Alternative #3, natural management with the goal of long-term water quality protection. These alternatives are considered in detail, and the justification for selecting Alternative #2 is described.

This section next details forest management objectives for the Quabbin watershed, designed to accomplish the selected alternative. It reviews the influence of natural disturbance, soils/species suitability, and the current condition of regeneration. It then outlines silvicultural activities that will first provide for the establishment of regeneration and that will create, over a 60-year period, the stable, multi-layered, watershed protection forest that is the ultimate goal of MDC's watershed forest management operations. Specific policies are described regarding the management of currently open lands and MDC-owned, off-watershed land.

*Key Points: The three forest management alternatives considered are as follows:

ALTERNATIVE #1: "ACTIVE MANAGEMENT FOR WATER YIELD ENHANCEMENT" - active management with the objective of moderately increasing water yields while minimizing impacts upon water quality and maintaining forests over most of MDC lands, utilizing commercial timber harvesting to maintain even-aged forest conditions and create forest openings. This alternative attempts to address the statutory requirement (Ch. 372 (1984), § 116) to consider water yield enhancement in the development of management plans.

ALTERNATIVE #2: "ACTIVE MANAGEMENT FOR WATER QUALITY PROTECTION" - active management with the goal of long-term water quality protection, accomplished by increasing the long-term stability of forest cover to mitigate future impacts from natural disturbances and air pollution, utilizing primarily uneven-aged silvicultural methods, accomplished through commercial timber harvesting, to deliberately increase diversity of tree sizes and species. This alternative attempts to address the statutory requirement to "assure the availability of pure water for future generations" (Ch. 372 (1984) § 105).

ALTERNATIVE #3: "NATURAL MANAGEMENT FOR WATER QUALITY PROTECTION"- limited management with the goal of long-term water quality protection, accomplished by the establishment of an equilibrium forest that persists for long periods of time and responds to natural disturbance, utilizing minimal silviculture. This alternative attempts to address statutory requirements for future water quality protection while also allowing natural growth and change in the forest, including creation of unmanaged natural areas and eventually old-growth habitat, and eliminating commercial forest management and active wildlife management.

Each of the forest management "alternatives" is described in terms of its underlying principles, general appearance, impacts on long-term water quality and water quantity, response to air pollution, implementation difficulties, and impacts on non-water resources.

Management to increase water yield would focus on even-aged silvicultural systems, regenerating the forest in large blocks to maximize water yield benefits. This system would be easiest to implement, but, while assuring water yield, presents greater risk to water quality protection.

Management to protect water quality, through the maintenance of stable forest cover, would focus on uneven-aged silvicultural systems, regenerating the forest through small openings. This system is the most difficult to implement, but provides long-term forest cover stability and vigorous nutrient accumulation, which in turn maintain water quality protection. The underlying principle of forest management geared toward protecting water quality is to decrease the amplitude, by increasing the frequency, of the wave of ecosystem disturbance. The system described maintains groups of vigorous young trees and individual or groups of older trees left to grow indefinitely, within the same forest. Overall, two thirds of the forest cover would be in younger, more vigorous cover and one third would be composed of older-aged trees.

The natural management alternative assumes that a stable equilibrium of forest processes would be achieved through the guided progression of natural succession - "the forces of aggradation and of decomposition would be approximately balanced" and "The forest stand would be considered all-aged and would contain a representation of most species, including some early-successional species, on a continuing basis." (Bormann and Likens 1979a:175). While this alternative would require the least amount of human intervention, the forest cover pattern would be unpredictable in the long run. Among the concerns is that large blocks of forest homogeneous in size and species content would develop in the absence of disturbance. These large blocks would then be susceptible to catastrophic disturbance. Consequently, water quality protection would also be subject to the random pattern of natural disturbance.

The Division has determined that the watershed protection function will be served best by a forest that is diverse in age, species, and vertical structure, is vigorously accumulating biomass and nutrients, and is continuously reproducing, i.e. the Alternative #2 forest. Management activities recommended in this plan attempt to mitigate the effects of natural disturbances. While the frequency of occurrence of catastrophic winds in New England cannot be changed, the resistance and resilience of a forest to such impacts can be enhanced. It is also one of the objectives of forest management on the Quabbin to identify stable soil/species combinations and to encourage their development through silvicultural operations.

The section describes the condition of regeneration in the Quabbin forest. Regeneration serves to anchor soils following disturbances, resists damage from many disturbances (due to its size and density), assimilates nutrients more rapidly than older vegetation, and shortens recovery times for reestablishing forests following disturbances. Regeneration success depends on seed sources, appropriate seedbed conditions for germination and initial establishment, and good conditions for development of the established seedlings. Adequate regeneration is defined as including the establishment of at least 2,000 stems per acre of seedlings/saplings greater than 4.5 feet in height, with a diverse species distribution including components of hemlock, pine, oak, birch, and maple.

Where the combination of closed canopies and prolonged deer browsing has created areas with very limited regeneration, initial treatments during this ten year period will include light, "preparatory" cutting, as well as limited "enrichment planting" to establish regeneration. Following successful establishment, silviculture will focus on releasing new forest layers in order to diversify the structure of

the watershed forest. Selection methods of uneven-aged management are generally the silviculture of choice, ultimately producing three or more forest layers in each area. The irregular shelterwood method (an even-aged hybrid) will be applied where it will produce the multi-layered forest more efficiently than the selection methods, in the short run.

For the ten years covered by the plan, silvicultural practices will occur within an average 1,500-2,000 acres per year, starting in areas where forest regeneration is not impeded by deer browsing and in areas that are the most critical to the water supply. Selection of specific sites where silviculture is planned for the next ten years was based on current forest conditions and exposure to hurricanes and other recurring impacts, such as gypsy moth infestation or root rot disease. Silvicultural priorities are described in detail by silvicultural practice and by forest type, and mapped on 94 Compartment maps in the plan's Supporting Appendices.

The level of silvicultural activity chosen allows MDC to "condition" the Quabbin forest into a "protection" forest over a 50-60 year period. Specific composition of forest layers is outlined for forests located in areas exposed to damage from insects, diseases, and storm damage, and those in more sheltered, less damage-prone areas, so that the projected damage from a large-scale disturbance is reduced. Of the 14,843 acres where silviculture has been mapped for completion during this decade, 1,185 will be thinnings in pine plantations, 423 will be thinnings in younger hardwood types and 13,235 will be various regeneration cuts in hardwood, softwood, and mixed forest types. Regeneration cuts, which remove up to 1/3 of the overstory in single trees and small groups, will maintain the overall integrity of the forest canopy, while a young forest is established slowly across the managed forest. In the absence of natural disturbances, one-third of the forest overstory, distributed across the entire landscape, would grow to 100-150 years old during the next 50-60 years. MDC silvicultural goals do not include a maximum age or size of tree to be grown on the watershed; instead, large older trees are balanced with smaller, younger trees.

MDC will increase its tree planting and site preparation practices, especially in areas of high importance to the water supply, to assure the quick establishment of young forests.

While some open areas on Quabbin will necessarily remain open (roads and utility rights-of-way, for instance), approximately 3,000 acres are being considered for reforestation. The value of maintaining specific open lands will be weighed against the value of replacing open cover with forest cover.

The MDC owns approximately 4,400 acres of land that are immediately adjacent to, but not actually on the Quabbin Reservoir watershed. Where these lands are not critical to water protection for MDC or other reservoirs, they will be considered for secondary uses such as active wildlife management.

Best Management Practices for Forest Management

*Contents: The key to low impact silviculture is in on-ground supervision and planning. MDC has drafted detailed policies and procedures covering these activities.

*Key Points: MDC has specifically outlined its "Best Management Practices (BMP's) for Forest Management". In all cases these BMP's match or exceed the BMP's included in the state's Forest Cutting Practices and Wetlands Protection laws. The BMP's specify equipment, harvesting systems, and limitations around sensitive sites. Detailed timber contract specifications protecting the water and natural and cultural resources are outlined. MDC natural resources, environmental quality, and archaeological staff will review all silvicultural and road work plans as outlined in internal review policies.

Wildlife Management Activities:

Assessment of Impacts of Planned Watershed Management Activities on Wildlife

*Contents Land management activities that alter vegetation and other habitat conditions have corresponding impacts on the wildlife community in that area. Some of the likely impacts associated with the habitat changes that will result from the implementation of this plan are discussed.

*Key Points Changes in wildlife habitat conditions on Quabbin will result from the planned forest management activities, but also from the control of deer browsing impacts. The net result will be increased structural diversity of the forest cover on much of the Reservation. These changes will occur gradually over the next several decades, but should begin to be evident during this management period. Overall wildlife diversity on the reservation will likely increase, as species that utilize lower and middle strata of forest cover will increase. Decreases in those species that prefer closed-canopy, open-understory conditions will also likely occur. Species utilizing blocks of open land or early-successional habitats will continue to be relatively uncommon.

Best Management Practices for Wildlife Management

*Contents: Given that the forest management program described in this plan can result in substantial changes in wildlife habitat, one of the key elements of the wildlife management program is recommending BMP's and specific actions to minimize the negative impacts and maximize the benefits of MDC's silvicultural operations, on wildlife.

*Key Points: MDC will maximize benefits and minimize negative impacts on a variety of wildlife species by: observing buffer zones around rare species habitats, focusing silviculture in concentrated areas each ten years, using a low intensity of management whereby each site is treated on an average of every 25-30 years, conducting winter operations in certain areas and observing certain guidelines in the selection of trees to be removed and left (especially leaving large live and dead trees). Further, with this level of activity, abundant levels of dead and downed material will accumulate and disturbance associated with management activities will be infrequent.

Population or Impact Control Plans

*Contents: Due to their potential negative impacts on water quality, forest conditions, or infrastructure integrity, certain wildlife species require direct management attention. In this section, specific management recommendations are described for deer, beaver, gulls, geese, and burrowing animals.

*Key Points: Deer impact programs will be continued as outlined in the 1991 Deer Impact Management Plan. A program of harassment of gulls and geese using non-lethal means will be carried out with the goal of moving congregations of these birds away from the area around the Chicopee Valley Aqueduct. Beaver impact management will mainly involve non-lethal means (e.g., tree fencing, flow pipe installation). When non-lethal methods are ineffective or inappropriate, lethal trapping will be done through site specific permits with a licensed trapper. These limited situations might include: beaver populations that may threaten the intakes with *Giardia* contamination (including stream and reservoir locations); beaver dams with a history of, or high potential for washing out in storms; dams that threaten rare or uncommon species; dams that preclude the use of necessary access roads; and locations that threaten the proper functioning of water supply infrastructure (dams and road culverts). Beaver control will be evaluated on a case by case basis.

Active Management for Selected Wildlife Species

*Contents: In areas with a lower importance to the maintenance of water quality, MDC will focus on actively managing habitat for certain uncommon and rare species.

*Key Points: Several target species were selected by MDC staff with the assistance of staff from the Mass. Natural Heritage and Endangered Species Program and other agencies and organizations. Specific habitat management guidelines for these species will be developed and implemented during this management period.

Cultural Resource Management Plan:

*Contents: The importance of policy with regard to cultural resource management is emphasized.

*Key Points: With the assistance of the MDC Chief Archaeologist (a position not existing at the writing of the 1986 Management Plan), two consultant studies of the archaeological resources at Quabbin (done in 1987 and 1990), and a study completed in 1994 by Boston University, specific BMP's are outlined for proactive management to protect important cultural sites and for minimizing negative impacts from watershed management activities on cultural resources.

Focusing Management Objectives - Cumulative Sub-basin Analysis:

*Contents: As this plan focuses on assuring high water quality in tributaries, MDC has adopted an innovative approach to identifying priority areas for its management work, chiefly in the areas of forest management, land acquisition, and wildlife impact control.

*Key Points: Using experience from MDC and outside experts and the information contained in Sections II-IV, MDC will evaluate the relative importance of each of the many small basins that make up the Quabbin Watershed. MDC will use several key criteria (such as slope, bedrock and surficial geology, soils, cover type, and distance to aqueducts) to evaluate the relative importance of each basin for water supply purposes. This process will help focus MDC's efforts in forest management, land acquisition, and wildlife impact management where they will benefit water quality the most. This basins model will also be used to locate multiple-use activities that are secondary to the purpose of water supply management, such as natural areas management, active wildlife habitat management, and timber management for revenue generation. The use of the basins model will evolve over this management period.

VI. Research

*Contents: Three specific research projects are outlined and funding to begin the projects is committed. Priorities are listed for other monitoring, inventory, and research activities.

*Key Points: Projects to be initiated with MDC funding include a determination of appropriate models of stream water quality and quantity, given different forest cover, the study of water quality in beaver-impacted areas, and the impact of logging on water quality in adjacent streams. Other research priorities include: monitoring of Quabbin understory recovery, determining optimal riparian cover, evaluation of access road conditions, inventory of Quabbin plants, inventory of dead and down woody material, comparison of actively managed and passively managed forests, additional analysis of CFI data, and additional surveys of wildlife populations.

VII. Public Involvement

*Contents: The strategy for regular involvement of the public in the development of management plans is outlined.

*Key Points: The framework and purposes of public involvement are outlined. The plan will be updated each year after a public workshop. A description of all planned silviculture will be placed in a notebook in the Quabbin Visitor Center prior to its occurrence, so that the general public can provide comments. A Science and Technical Advisory Committee consisting of experts in the fields of natural resources and watershed management will be formed to advise MDC on annual plan revisions, sub-basin modeling, future designations of lands with special management restrictions, research priorities, and research quality control.

SUMMARY

The Quabbin Land Management Plan, outlined above, represents a comprehensive approach to the management of New England's largest water supply and one of the largest unfiltered supplies in the United States. One of the main tenets of this plan is that a proactive and long-range approach is well justified given the importance of the task at hand. This plan synthesizes a large body of research, literature, and staff expertise on a focused goal of protecting and enhancing the natural filtration capabilities of the 58,000 acres of MDC watershed land surrounding the Quabbin Reservoir. It is the hope of the MDC Natural Resource staff that this plan has been sufficiently well-researched and constructed to serve as a model for other New England water supply land managers.

I. Introduction, Mandates and Statement of Mission

Perhaps no other issue in the management of natural resources is as critical to the well-being of our society as the provision of pure and adequate drinking water supplies. This is especially true in recent years, given the frequency with which incidents of contaminated wells, fouled lakes and water-borne disease outbreaks have been reported. The protection and careful management of public water supply reservoirs and watersheds will thus continue to be of utmost importance in future years.

This document outlines a plan for protecting and managing the Quabbin Reservoir watershed - the heart of an extensive water supply system that serves almost 2.5 million people in metropolitan Boston and Springfield areas.

A. Agency Mission and Mandates

Quabbin is managed and administered by the Metropolitan District Commission (MDC), Division of Watershed Management (DWM or "Division"). The MDC is a state agency within the Executive Office of Environmental Affairs, and is charged with coordinating the enhancement of the quality of living within the metropolitan Boston area. The DWM was established by Chapter 372 of the Acts of 1984, which provided its primary mandate. Among other things, this act directed the Division to *"...utilize and conserve...water and other natural resources in order to protect, preserve and enhance the environment of the commonwealth and to assure the availability of pure water for future generations."* In addition, the DWM was directed to periodically prepare watershed management plans that shall provide for *"...forestry, water yield enhancement and recreational activities."*

In order to meet the above legislative mandates, the DWM has established programs in Environmental and Water Quality, Engineering and Construction, Infrastructure Maintenance, Public Education and Land Management. The long-term goals of the DWM are to:

- assure availability of pure water for present and future generations,
- effectively manage, protect, conserve and enhance the natural and structural resources under the responsibility of the DWM to ensure public health and safety,
- prevent adverse environmental impacts from degrading watershed resources,
- provide educational programs in order to protect watershed resources,
- manage or conduct research that guides and assists the effective management of watershed resources,
- formulate emergency contingency plans that address existing and potential threats to DWM resources,
- serve as a national role model for other watershed management agencies.

Chapter 92, Section 105 of the Mass. General Laws further defines DWM's mission, in stating that the Division *"...shall be subject to the provisions of chapter seven hundred and thirty-seven of the acts of 1972."* Chapter 737, commonly referred to as the "Kelly-Wetmore bill", included far-reaching

guidelines on the types and extent of both public and management activities permitted on Quabbin lands. Section 8 of Chapter 737 states that: *"Lumbering or logging operations shall be permitted...to the extent and for the purpose of maintaining and conserving its forests in a healthful state of natural ecological balance consistent with reservoir and watershed purposes...".*

Both MGL Chapter 92 and Chapter 737 set forth clear and consistent authority providing for the active management of the watershed and its natural resources.

Chapter 737 is the only statute that makes direct mention of wildlife management on DWM watershed lands, although taken as a whole, it still makes for an ambiguous mandate regarding the direction of that management. The following clauses are included in Chapter 737:

Section 2: "The natural ecology of the district shall be maintained and it shall be conserved in its present degree of wilderness character..."
"...[it] shall be protected in its flora and fauna in all reasonable ways to assure the balanced wildlife habitat"
"...no act shall be undertaken which will adversely affect the balance of nature..."
Section 8: "...lumbering and logging operations shall not be of a tree farming nature...wherein wildlife habitat or food chain growth is adversely affected."
Section 9: "...Prescott peninsula shall be set aside as a natural site for ecological and wildlife study..."

One other statute addresses wildlife management activities on water bodies used for domestic water supply (Chapter 111, Section 174A). This statute authorizes the Division of Watershed Management to:

"...take such reasonable means and use such appliances and weapons as...will prevent the defilement of said waters by gulls or terns...".

B. Plan Overview

In formulating this management plan, DWM staff has provided the necessary interpretation of the above mandates so that they could be transformed into specific management goals and direction. Although this plan addresses various natural resources, it is mainly focused on managing for the Division's primary purpose - the long-term protection and maintenance of water quality. The land management strategies outlined in the plan are primarily designed to establish and maintain the most effective and practical watershed cover in order to maximize the natural filtering capability of the lands surrounding the Quabbin Reservoir.

The plan calls for the maintenance of a diverse, multi-layered forest cover on much of the watershed. This decision was based on the review and analysis of a multitude of documents, studies, and professional opinions, and represents the culmination of hundreds of hours of reading and discussions by DWM staff. As such, we feel that the management program described in the plan is both prudent and appropriate, given the current state of knowledge on watershed management.

However, MDC recognizes that the science of watershed management is far from exact, and that gaps exist in the current understanding of watershed relationships. Despite these gaps, the DWM is directed to act on the current state of knowledge, to manage under uncertainty. It is a fundamental

tenet of the growing field of "adaptive resource management" that tracking responses to management activities will provide empirical knowledge that is impossible to discover through modeling alone (see, for example, Walters, 1986). While the DWM values and utilizes a variety of modeling techniques (e.g. hurricane modeling), we believe it is appropriate to view management both as the prudent application of current understanding and as part of the effort to improve our models. Thus, this plan should be viewed as an "adaptive watershed management plan" or a "working hypothesis", to be applied but updated and modified as new information comes to light.

To achieve one of the main goals of this plan, i.e., the establishment of a diverse, multi-aged forest cover throughout the watershed, it is imperative that effective control over white-tailed deer browsing impacts be achieved. Thus, this plan is built upon the assumption that deer impacts on forest regeneration will not be a limiting factor during the management period.

This plan primarily focuses on management over the next ten years, but it also projects the forest cover and watershed conditions 60 years into the future. This long-range view is clearly consistent with Chapter 372, Acts of 1984, which directs the Division "to assure the availability of pure water for future generations". The importance of this long-range view is that it plans for the future integrity of the "land/forest filter" in the face of such events as hurricanes, floods, fires, insect and disease outbreaks, environmental pollution, and other impacts unknown to managers today.

During the preparation of this plan, a tremendous amount of useful information was researched, compiled and summarized. Much of this information was included in the early drafts of the plan since it formed the basis for many of the management proposals contained herein. However, to reduce the volume of this final plan, and to improve its readability, much of this background information has been moved to a separate document entitled "Supporting Appendices".

The plan itself includes sections on: 1) a Description of Quabbin Watershed Resources; 2) Principles Guiding Watershed Management; 3) a statement of the Division's Watershed Management Goals; 4) Management Plan Objectives and Methods; 5) Research priorities; and 6) Public Involvement. The plan is written so that the management plan components and research priorities sections are based on the sections that precede them. Readers wishing to understand more about the History of the Quabbin Forest, MDC's Land Acquisition Program, or those desiring a more detailed summary of current scientific literature on watershed, forest or wildlife relationships and management, are referred to the Supporting Appendices.

The programs and policies contained in this plan supersede those of the Ten Year Forest and Wildlife Resource Management Plan for the Quabbin Watershed (Spencer and Lyons, 1986) and update and change some of the policies outlined in the Quabbin Reservation White-Tailed Deer Impact Management Plan (MDC, 1991), especially in the area of forest management.

II. Description of Quabbin Watershed Resources

A. Quabbin Watershed Ownership and Land Use

The Quabbin Reservoir watershed (including the reservoir) includes approximately 120,000 acres. Of this area, MDC has care and control of 64% (20% is the reservoir and 44% is MDC lands). Of the remaining 36% of the watershed of which MDC does not have care and control, 7.2% or 8,674 acres are maintained in undeveloped forest cover by other state agencies (the Department of Environmental Management and the Department of Fisheries, Wildlife, and Environmental Law Enforcement) or private organizations (Mass. Audubon Society, Trustees of Reservations, and Harvard University) (Table 1). Of the remaining 29% of the watershed that is private, unprotected lands, 1% is residential development, 1.2% is in agriculture, .6% is wetland, .9% is water, 1.4% is open land, and 24.1% is forest (MDC/MWRA 1991).

From a water supply viewpoint, the land use pattern on Quabbin watershed is favorable, with very little of the land currently developed or in inappropriate uses. Since a majority of the land in the watershed is under MDC control, the management of these lands can have a significant effect on the waters flowing into the reservoir. It is noteworthy that more than 24% of the watershed (28,846 acres) is in private forest cover. The management of these lands in future years may have a measurable effect on tributary water quality.

Table 1: Non-MDC Quabbin Watershed Landuse (from Watershed Protection Plan; MDC/MWRA 1991)

LANDUSE	PRIVATE (acres)	%	PUBLIC (acres)	%	TOTAL (acres)	%
Residential	1179	2.7	27	0.1	1206	2.8
Industrial	44	0.1		0	44	0.1
Commercial	8	0		0	8	.0
Recreation	44	0.1		0	41	0.1
Cropland	1064	2.4	28	0.1	1092	2.5
Animals	191	0.7		0	191	0.4
Wetland	769	1.8	282	0.7	1051	2.5
Forest	28846	66.2	8207	18.9	37053	85.1
Waste Disposal	13	0		0	13	.0
Water	1071	2.5	13	0	1084	2.5
Open	1626	3.7	118	0.3	1744	4.0
TOTALS	34852	80.1	8674	19.9	43526	100%

Private = privately owned lands (unprotected)
Public = other state-owned lands, for protection/conservation

B. Physical Characteristics of Quabbin Watershed Lands

1. Soils

For the purposes of watershed management, the Quabbin soils have been grouped and mapped into five classes (Table 2), based on the most current United States Department of Agriculture Soil Conservation Service publications. These classifications are based upon soil depth and drainage characteristics.

1. *Excessively drained soils*: Excessively drained soils are usually very coarse textured, rocky or shallow. Water is removed from the soil very rapidly. These soils are thick loamy sands occurring primarily on glacial outwash. The principal soils occurring most frequently in these areas are the Hinckley, Merrimac, Windsor, Carver, and Suncook series. These are relatively deep soils (>65") and occupy 80% of the area. Inclusions[1] of the Deerfield and Sudbury series occupy the remaining 20% of the area and are located usually in the lower landscape positions. They are moderately well-drained fine sandy loams, usually very deep and very stony.

2. *Well drained thin soils*: These soils are commonly of medium texture. Water is removed from the soil fairly rapidly, but is available to plants during most of the growing season. The principal soils occurring in these areas are the Shapleigh series, which are shallow soils (1"-24") formed in glacial till located on the sides and lower slopes of hills and ridges. The other major series is the Charlton-Hollis-Rock outcrop complex occurring in similar landscape positions. This complex consists of 45% deep Charlton soils, 10% shallow Hollis soils, 10% rock outcrops, and 35% other soils. These other soils, listed as inclusions, are Paxton soils, which are located on hills and knolls, Ridgebury and Woodbridge soils, which are located on the lower landscape positions, and Brookfield and Brimfield soils, which are located in the transition areas.

3. *Well drained thick soils*: These thick (24"-65") soils are formed in loamy and sandy glacial till on uplands. The Canton, Gloucester, and Charlton series are found generally on the lower sides of hills and ridges. Various inclusions of Hollis, Ridgebury, Montauk, Woodbridge, Scituate, Essex, Paxton, and Brookfield series may be found at any given location. The Paxton, Essex, and Montauk series can generally be found on the tops and upper parts of hills and ridges. Inclusions of Brookfield, Canton, Brimfield, Charlton, Woodbridge, Ridgebury, Scituate, and Gloucester series may be found scattered throughout the upper portion of the landscape.

4. *Moderately well drained soils*: Moderately well drained soils are wet for only a short period during the growing season but the removal of water is somewhat slow during these times. These soils consist of very deep, (to 65" and greater) fine sandy loams. The Sudbury and Deerfield series are formed on outwash plains and terraces and occupy nearly level positions on the landscape. Other soil inclusions found within these types have been identified as the Merrimac, Walpole, Scarboro, Hinckley, and Windsor series. The Woodbridge series are formed on glacial till on uplands and are generally found on the tops of upper parts of hills and ridges. Inclusions of Charlton, Paxton, Canton, Montauk, and Ridgebury may occur within the Woodbridge series. The Scituate soil series, formed in glacial till on

[1]Because of the scale used in mapping, small areas (generally less than 5 acres) are not shown separately on soil maps. These small areas are known as inclusions.

the uplands, is commonly found on the lower slopes of hills and ridges. Inclusions within this type are the Montauk, Canton, Woodbridge, Paxton, Ridgebury, and Walpole.

5. *Poorly to very poorly drained soils*: Poor drainage usually results from a high water table where water is removed so slowly that the soil is saturated or remains wet for long periods during the growing season. These soils are very deep, extending to a depth of 50" or more, and consist of fine sandy loams and mucks. The Ridgebury and Whitman series are found in depressions and in low areas on uplands. Inclusions of Woodbridge, Paxton, Scituate, and Swansea series comprise about 20% of these soils. Freetown and Swansea mucks are organic soils formed in depressions and on plain areas. These types can also contain about 20% included soils such as the Whitman, Scarboro, Ridgebury, and Walpole series. The Scarboro-Rippowam complex and the Walpole series occur in depressions and along drainage ways. The complex includes about 40% Scarboro, 30% Rippowam, and 30% other soils, while the Walpole has approximately 20% included soils from the Sudbury, Deerfield, and Swansea series.

Table 2: Acres of Composite Soil Type by Block

Types:

1 = Excessively Drained Soils
2 = Well Drained Thin Soils
3 = Well Drained Thick Soils
4 = Moderately Well Drained Soils
5 = Poorly to Very Poorly Drained Soils

	COMPOSITE SOIL TYPES				
BLOCK	1	2	3	4	5
Hardwick	1548	4017	3469	2283	837
Pelham	429	3909	3623	2385	707
New Salem	2334	2705	3609	1145	1186
Prescott	612	6294	2619	1716	896
Petersham	862	2374	2065	3620	972
TOTALS	5785	19299	15385	11149	4598
PERCENT	10.3	34.3	27.4	19.8	8.1

Generally, the soil within the Quabbin Reservoir Watershed supports a wide variety of native tree species, most notably northern red oak, eastern white pine, red maple, sugar maple, and white ash. The dominant forest cover is oak with red maple occurring on the wetter sites and white pine dominating the drier sands and gravel (while white pine grows vigorously on moist soils, it competes poorly with other species on these sites during the establishment phase of the stand). Sugar maple and white ash are generally limited to less acidic soils with moderately high moisture content. The Division's efforts to create a resilient, low-maintenance watershed forest require consideration of site/species compatibility.

2. Hydrology

The Quabbin Reservoir drains a land area totaling approximately 150 square miles (96,000 acres). In order of size, the most important sub-watershed drainages include the East Branch of the Swift River (43.7 sq.mi.), the West Branch of the Swift River (12.4 sq.mi.), the Middle Branch of the Swift River (10.7 sq.mi.), the East Branch of Fever Brook (8.7 sq.mi.), Hop Brook (5.4 sq.mi.), the West Branch of Fever Brook (4.5 sq.mi.), and Dickey Brook (4.3 sq.mi.). The Ware River watershed, upstream from Shaft 8, is a major tributary to the Reservoir during high flow winter periods when diversion may occur. Within the portion of the watershed owned by the MDC, there are approximately 132 miles of streams, excluding intermittent streams, and 2,272 acres of wetlands, including year-round water bodies, but excluding vernal pools.

Annual precipitation since 1955 has averaged 45 inches per year, with a range from 29.7 inches in 1965 to 64.9 inches in 1955. Historically (1930 to 1979), September has been the wettest month, with an average of 4.11 and a maximum of 14.8 inches of precipitation, while February has been the driest month, with an average of 2.97 inches. Of the 45 inches of precipitation that fall directly on the 24,000 acre Reservoir surface, approximately 39 inches evaporate, for a net average gain of about 10 million gallons per day. The average precipitation yield to the Reservoir from the entire watershed is approximately 50%. The Reservoir, at full elevation of 530 feet, contains 412 billion gallons within a shoreline that totals 157 miles in length.

The hydrology of the watershed is strongly affected by the preponderance of forest cover. Forest cover has both positive and negative effects on water yield, with net yield the result of precipitation, evapotranspiration, interception, soil moisture and ground water storage. Watershed studies show that evapotranspiration losses from forests are significant, but highly variable, with water yield increases occurring when part or all of a forest cover is removed or replaced by herbaceous vegetation. The most significant yield differences among forest covers are between conifers and deciduous trees. (Note that the current Quabbin forest is approximately 2/3 deciduous and 1/3 conifer, primarily pine.) In general, forest canopy interception (due to evaporation) and evapotranspirational losses are greater for conifers than for deciduous species, although this varies with stocking and with storm characteristics (deciduous forests average 13% overall interception losses, while coniferous forests average 28%, Dunne and Leopold 1978). The creation and maintenance of open land generally reduces interception and evapotranspiration losses and can result in a significant increase in yield.

The manipulation of forest cover also affects soil infiltration, storage, and overland flow. While the actual operating model in any given forest is complex, two factors related to forest manipulations are key - organic matter content and pore space. New England forest soils are generally hydrophilic (wettable), and the accumulation of organic matter plus the burrowing activities of soil organisms create a sponge-like forest floor with a large potential water infiltration and storage capacity. The actual depth of the organic layer is influenced directly by species composition and stocking, with the greatest accumulations occurring beneath dense stands of conifers, where cool, acid conditions prevent the decay of organics. While there are differences between species in root depths, tree roots generally penetrate deeply into soils, ultimately creating macropores and increasing water storage capacities within and beneath the organic layers of the soil. The maintenance of a forest cover prevents the sharp rises in soil temperature that can cause the rapid decay of organic matter and thus reduce the water storage and filtering capacity of the forest. Therefore, the replacement of trees with herbaceous cover may reduce water storage.

3. Topography

The following description of Quabbin topography is quoted directly from the joint MDC/MWRA "Watershed Protection Plan", (MDC/MWRA 1991), Section 2.4.1:

"The Quabbin Reservoir is located on the west flank of the eastern upland of south-central Massachusetts, an area characterized by extensive preglacial erosion and weathering followed by two major continental glaciations during the Pleistocene Epoch.

The topography of the eastern part of the Quabbin watershed is irregular with moderate slopes, while the western part is characterized by two well defined, steeply sloped ranges oriented north and south through the length of the watershed. Elevation ranges from 530 feet (full pool elevation) to over 1,200 feet with several hills exceeding this elevation (the tallest hill on the watershed is Prospect Hill in Phillipston, at 1383'). The topography is characterized by north and northeast trending hills and relatively narrow valley bottoms....The hills generally expose bedrock on their summits and flanks. Surficial deposits of ablation till and basal till blanket these upland slopes with a thin veneer ranging from 5 to 20 feet or more in thickness. The valley bottoms and lowlands are generally filled with stratified glacial outwash deposits consisting of varying amounts of silt, sand, and gravel. Glacial till is the most extensive deposit in the watershed. The till is overlain by a thin mantle of eolian silt and very fine sand...."

Based on GIS data acquired by Division staff for hurricane simulation modeling (Ottenheimer 1992), the MDC lands within the watershed fall within three slope categories, as follows:

0 - 5 degrees	21,809 acres	(38.7%)
6 - 10 degrees	21,032 acres	(37.4%)
> 10 degrees	13,490 acres	(23.9%)

Areas of "steep slopes" have also been digitized for MDC-owned Quabbin lands, based on visual estimates on USGS topography maps. In general, these are areas with gradients in excess of 20-30%. "Steep slope" areas are listed below by Block:

Hardwick	490 acres	
New Salem	241 acres	
Pelham	321 acres	
Petersham	121 acres	
Prescott	538 acres	
TOTAL	1,711 acres	(approximately 3% of MDC lands)

4. Developed Areas

There is a very minor component of developed lands within the 58,000 acres of MDC lands at Quabbin. MDC has various buildings and structures at the following locations: main administration complex at Winsor Dam, maintenance facilities and three residences, Quabbin Hill tower and restrooms, restrooms and fishing fee collection stations at Gates 8, 31 and 43, and forestry office and

garage at Elm Street, New Salem, power station below Winsor Dam and shaft intakes at Winsor Dam and Shaft 12. There are 11 miles of paved roads in Quabbin Park, and an additional 13 miles of paved roads at Gates 30, 31, 40, 43 and 44. The Division maintains approximately 210 miles of unpaved access roads totaling approximately 686 acres. Several cleared utility rights of way cross MDC Quabbin lands and cover approximately 176 acres.

5. Other Open Lands

Open MDC lands at Quabbin include approximately 400 acres of pine plantation clearings done in the 1980's and 320 acres of open areas in Quabbin Park and unregenerated forest openings caused by natural disturbances. Approximately 2,272 acres of open wetlands are mainly the result of beaver activity over the past several decades. Approximately 4,598 acres are in poor to very poorly drained soils, which is a rough approximation of the area of wooded and non-wooded wetlands at Quabbin. The Division is currently having aerial photos analyzed that will very accurately map the wetlands at Quabbin.

C. Quabbin Forest and Wildlife Conditions

1. Forest

a. Forest Types and Ages

The current Quabbin forest consists of hundreds of stands, each defined as "a contiguous group of trees sufficiently uniform in species composition, arrangement of age-classes, and condition to be a distinguishable unit" (Smith 1986). The simplest Quabbin stands are even-aged conifer plantations of a single species. Complex stands are multi-aged, with a stratified mixture of both shade-tolerant and shade-intolerant species. Quabbin's largest stands are even-aged oak stands, some consisting of several hundred contiguous acres. With the passage of time, stand boundaries that were created and maintained by past land use practices will fade and stand definition will become less important. However, boundaries between forest types will remain evident where there are differences in site characteristics, and these type changes will dictate some differences in management (for instance opening sizes and choices of species where underplanting is required).

Acres in forest types currently under management (Table 3) were obtained from MDC maps that were completed in 1975. The Division plans to update typing to account for changes since 1975 and to digitize this new typing for use in GIS analysis and mapping.

The current Quabbin forest originates primarily from farm abandonment at the turn of the century, openings caused by the hurricane of 1938, and plantation establishment by the MDC, on open land, at about the same time. Consequently, the 47,000+ acres of forest currently under management is primarily of two ages: 19,000 acres of 55 year old forest and 28,000 acres of 90+ year old forest. The exceptions to this generalization are small areas where deer browsing has been moderate (traditional hunted areas) and new forest layers have become established.

Table 3. Acreage of Managed Forest on Quabbin by Type.

FOREST TYPE	ACRES	PERCENT
Oak	22,961	48
White pine	10,078	21
Birch/red maple	5,173	11
Red pine	3,179	7
Northern hardwood	3,137	7
Hemlock	2,281	5
Spruce	556	1
TOTALS	47,375	100
HARDWOOD SOFTWOOD	31,271 16,104	66 34

b. Forest Changes - 1980-1990

1) Continuous Forest Inventory

Continuous Forest Inventory (C.F.I.) plots were established throughout MDC lands in 1960. These are one-fifth acre (53' radius) permanent plots located at the intersections of a half-mile grid (each "represents" 160 acres). The plots were originally remeasured every five years, but are currently on a ten-year schedule. 321 C.F.I. plots were measured in both 1980 and 1990, and are summarized here. New plots are added as land is acquired, plots that have been converted to treeless wetlands are eliminated, and plots on islands are remeasured every 20 years.

Every tree greater than 5.5" in diameter at breast height (DBH) on each plot is numbered and measured for DBH and total height, and given a forest product rating (e.g. sawlog, fuelwood, wildlife tree). This product classification is a standard C.F.I. entry, which indirectly serves as a ranking of the tree's vigor. Plots are not managed differently than the area in which they fall; if that area receives silvicultural treatment, the plot receives the same. Records are kept to distinguish trees that have been cut from those that died.

Information collected from C.F.I. is most useful to Quabbin managers for following changes in species composition, in growth and death rates, in the distribution of size-classes, and in regeneration. It has also been used to estimate volumes of various products, but stocking, described in terms of basal area, relates more directly to watershed forest functions. Stocking is defined as "the extent to which a site is occupied by trees, compared to the maximum occupation possible on that site at the given age of the stand" (see Glossary of Terms). This stocking, summarized in various ways below, defines the density and structure of the Quabbin "protection forest".

2) Species Distribution

Species distribution (Figures 1 and 2) is calculated from C.F.I. plots based on the percent of the total basal area on all plots in either North or South Quabbin (Gate 40 and Gate 16 are the approximate N/S dividing lines). Changes in the past decade are a combination of growth, harvest, and mortality. Approximately 55% of the total basal area has steadily been composed of oaks and white pine, with just slightly more oak overall. Maples account for 14-17%; birches 8%. Red pine and hemlock combine to make up 15% of the basal area in both North and South Quabbin, but they swap importance - hemlock is 10% of North Quabbin's basal area, while red pine is 10% in South Quabbin. Ash is the most important of all other species, averaging about 3% of the total basal area during the past decade.

3) Size Distribution

The correlation between diameter at breast height (dbh) and age is only very approximate and varies a great deal among species, sites, and stocking densities. However, the distribution of size classes across the watershed is indicative of structural diversity. Quabbin C.F.I. plots divide trees into three conventional size classes: sapling/pole (5.6" to 9.5" dbh), small sawlog (9.6" to 15.5" dbh), and large sawlog (15.6" dbh and up). In 1990, there were 10,290 living trees on all Quabbin C.F.I. plots combined (representing an average of 150-200 trees per acre on the entire watershed). Table 4 shows the breakdown of these trees by size class and percent of both the total number of trees and the total basal area (a measure of stocking density based upon tree diameter) on all C.F.I. plots combined.

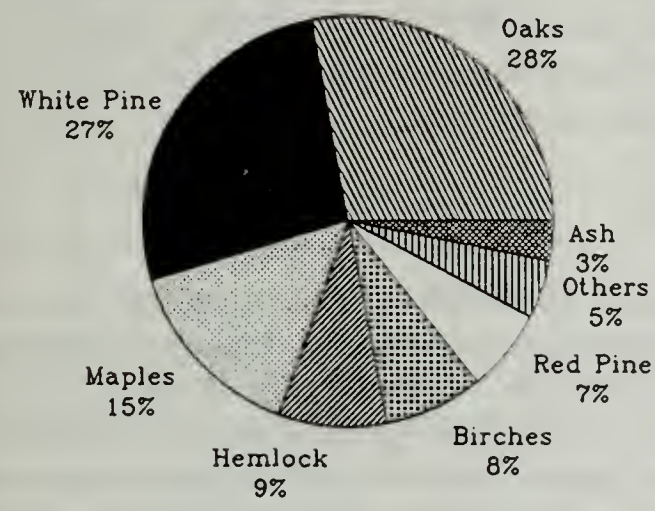
Table 4. Size Distribution of Trees on C.F.I. Plots, Quabbin Watershed - 1990.

Size Class	# of Trees	% of Total #	% of Total BA
< 9.6" dbh	5633	55	27
9.6 - 15.5" dbh	3708	36	44
> 15.5" dbh	949	9	29

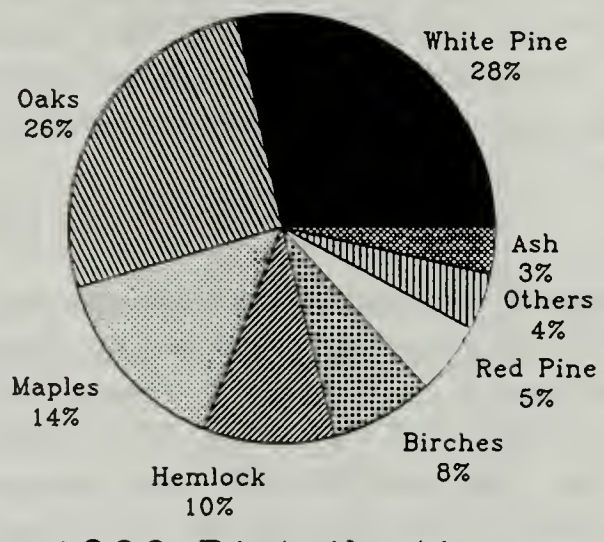
Approximately 73% of the total stocking on C.F.I. plots occurs in diameter classes of 10" (9.6" to 10.5" DBH) and up. Figure 3 shows the changes in these distributions from 1980 to 1990.

Figure 1:

North Quabbin CFI Plots
Percent of Total Basal Area 1980–90



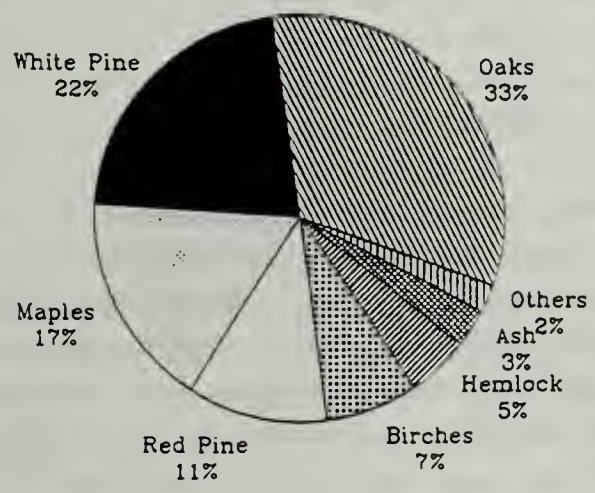
1980 Distribution



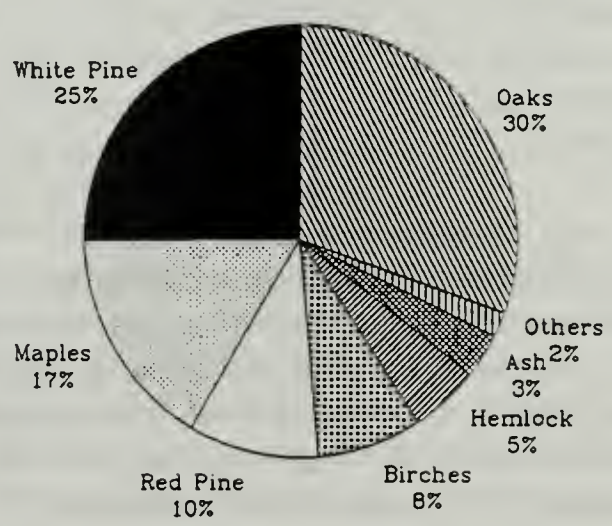
1990 Distribution

Figure 2:

South Quabbin CFI Plots
Percent of Total Basal Area 1980–90



1980 Distribution



1990 Distribution

From 1980 to 1990, there was a large reduction in the number and total basal area of trees in the smaller size classes. Of the 7,219 trees < 9.6"dbh in 1980, 1,553 (23%) died or were harvested and 1,279 (18%) grew into larger diameter classes. While 1,246 "new" trees grew into this smaller diameter range (grew past the 5.6" dbh minimum during the decade), there was still a net reduction of 1,586, or 22% in the number of trees in the class, and a net reduction of 21% in basal area (despite growth of the trees that stayed in this class through the decade). The reduction in smaller size classes was accompanied by increases in the larger size classes. The most dramatic change is in the largest class, trees greater than 15.5" dbh. This class grew from 610 trees and 1,174 square feet of basal area in 1980 to 949 trees and a basal area of 1,879 square feet in 1990, jumps of 56% and 60% respectively. This occurred despite death and harvesting in this size class, which totalled approximately 10% of the 1980 numbers and basal area in the class.

4) Growth and Death

Changes in basal area of the most prevalent species occurring on the Quabbin, from 1980 to 1990 (Table 5), are a combination of growth, death, and harvest removals. Including minor species, the total basal area of all Quabbin C.F.I. plots grew from 5,846 square feet in 1980 to 6,484 in 1990, a net change of 11%, or 1.1% per year for the period. This figure includes growth of trees alive and recorded in both 1980 and 1990, plus trees that grew beyond the 5.6" minimum dbh ("new" trees) during these years, minus trees that died or had been cut since 1980. "New" trees account for 274 square feet of additional basal area, which is 18% of the "growth" statistic. For all species combined, 7.9% of the 1980 basal area died and 7.2% was cut from 1980 to 1990.

Average annual diameter growth rates for major species during the 1980-1990 period are listed below, calculated from trees that were measured in 1980 and still living in 1990:

Species	North Quabbin	South Quabbin
Wh Pine	0.15"/year	0.15"/year
Red Pine	0.14	0.08
Hemlock	0.13	0.14
Red Oak	0.14	0.13
Black Oak	0.10	0.10
White Oak	0.07	0.07
Sugar Maple	0.07	0.10
Red Maple	0.09	0.07
Black Birch	0.10	0.11
White Birch	0.08	0.06
White Ash	0.12	0.11
Hickory	0.06	0.09

The large discrepancy between North and South growth rates for red pine is due primarily to silvicultural differences. Most of the red pine in the South Quabbin remained untreated during the decade, while extensive areas of red pine were either thinned or cleared in the North. This harvesting activity, motivated by water yield objectives during the 1980's, also shows in the summary of basal area changes (Table 5.). Nearly 20% of the total 1980 basal area of red pine was cut during the ensuing decade. Despite this cutting, which included 400 acres of clearings, the total basal area of the species (throughout the Quabbin) declined by just 4%.

Table 5. Changes in C.F.I. Basal Areas 1980 - 1990

										Net Change	
Species	1980 BA	Died	%	Cut	%	Growth	%	New	1990 BA	BA	%
White Pine	1455	60	4.1	113	7.8	413	32.2	43	1759	304	20.9
Hemlock	413	32	7.7	5	1.2	107	28.5	42	525	112	27.1
Red Pine	486	16	24.9	30	19.8	93	24.9	1	446	-3	-3.7
Sugar Maple	97	4	7.2	5	5.2	13	15.3	1	102	5	5.2
Red Maple	486	60	8.2	43	19.8	138	11.9	42	892	77	9.4
Red Oak	29	60	4.1	41	9.9	214	25.5	3	1076	-3	15.9
Black Oak	497	92	11.0	57	11.5	93	24.9	17	446	-51	-10.3
White Oak	274	37	13.5	27	9.9	32	15.2	7	249	-25	-9.1
Yellow Birch	77	92	2.6	7	11.5	10	21.9	1	93	16	20.8
Black Birch	274	23	11.0	5	9.9	55	25.5	30	406	-3	20.9
White Birch	123	60	21.1	7	9.9	16	11.0	1	112	-11	20.8
White Ash	182	15	8.2	7	9.9	56	33.7	5	231	49	26.9
Hickory	73	4	11.0	0	9.9	10	15.4	1	79	6	5.2
Black Cherry	29	4	13.8	3	10.3	4	18.2	1	27	-2	15.9
Poplar	15	4	24.9	1	6.7	2	24.9	0	12	-3	26.9
TOTALS	5711	451	7.9	413	7.2	1250	25.8	274	6371	660	11.6

Much of the cutting of white and black oak during the decade was salvage cutting of trees affected by gypsy moth infestations. White oak is especially vulnerable to these attacks so that much of what was cut was dead or dying. Black oak is often less vigorous than red oak in mixed stands and was removed from damaged stands to improve stand vigor. Overall, less than 5% of the 1980 basal area of red oak was cut during the decade.

Despite cutting of 8% of the 1980 white pine basal area and new additions of less than 5%, net basal area growth for this species approached 21%. For trees that were alive and measured in both 1980 and 1990 (i.e. excluding trees that died or were cut during the decade), white pine basal area grew in excess of 32%. This rate was exceeded only by white ash (33.7%), although hemlock basal area growth on trees alive and measured in both periods was close behind white pine, at 28.5%. These figures do not consider height growth during the period, which would put white pine far in excess of other species in terms of biomass or volume growth for the period.

With the exception of white and red pine, mortality rates exceeded harvesting rates for all species. The greatest differences were for white birch and poplar. For both species, mortality exceeded harvesting by about four times, and total loss exceeded total growth by 1.5-2.5 times. These are both short-lived pioneer species and it is not surprising to see them gradually eliminated from the maturing forest. Of greater concern are the losses of white and black oak. While salvage efforts have utilized some of the losses in these two oaks, mortality exceeded harvesting by 40-60%, and net loss of basal area for the two was 9-10%, despite good growth rates for the survivors. Overall, major

hardwoods declined from 59% of the total basal area in 1980 to 57% in 1990, with corresponding gains in major softwoods.

5) Volume Information

It is conventional in forestry to inventory volumes of standing timber, by type and species, in order to project volume growth and calculate estimates of "rotation" and "allowable cut". Division foresters collect information on merchantable product volumes on C.F.I. plots, but it is not tabulated because volumes of saleable products do not drive Division management objectives. Silviculture has been accomplished through private timber contractors on the Quabbin (yielding a net gain to the water consumer), but the primary goal has been production and protection of water. Timber production goals have never been set for the watershed.

The Division's "production goals" have been based more on an attempt to modify age/size/species diversity and distribution on areas where this maintenance is of the highest priority. These goals are derived from an evolving assessment of long-term and immediate threats to the forest. For instance, cyclical gypsy moth infestations have increased the priority set on salvaging damaged oak and on planting pine in affected areas, to increase species diversity and reduce the threat of future infestations.

In the interest of defining the level of "intensity" of forest management on the Quabbin, it may be worth comparing the volumes of timber produced by Division practices, to rough estimates of the annual growth of the Quabbin forest. From C.F.I. plots it has been estimated that the most productive sites are capable of a mean annual increment (average over life of stand) in excess of 500 board feet per acre per year, with periodic increments (annual average) approaching 1000 board feet per acre per year. The least productive sites grow approximately 100 board feet per acre per year. It is unlikely that the average mean annual increment is less than 200 board feet per acre per year.

Of the 58,000 acres of MDC Quabbin watershed land, approximately 47,000 are currently under active management (excluded are the Pottapaug Natural Area, wetlands and inaccessible areas, recreation and administration sites, etc.). Using the average figure for growth, the managed land grows 200 board feet x 47,000 acres, or about 10 million board feet per year. The volumes of timber sold as a result of MDC silvicultural practices averaged 1-3 million board feet annually for the past decade, or 10-30% of the annual growth. A very rough estimate indicates there are 4-500 million board feet in standing trees on MDC Quabbin land, so that the annual volume removed has averaged approximately 0.5% of the total standing volume.

While it is not a Division objective to accommodate timber market demands, nor to employ a specific number of private timber harvesters or sawmill operators, these are clearly incidental benefits of the Division's watershed management practices. A wide variety of factors influence the final value and destination of raw forest resources withdrawn from Quabbin forests, making it difficult to derive precise "value-added" figures. However, the Generic Environmental Impact Report (GEIR) on Massachusetts Forestland Management Practices, prepared by the Department of Environmental Management in 1992, gives a rough estimate of the magnitude of this economic impact.

According to the GEIR, 72.6 million board feet were harvested in Massachusetts in 1988, with a stumpage value (the price paid to the landowner for standing trees) of $7.2 million dollars. In 1978, the total value of primary products shipped from Massachusetts sawmills (includes grade lumber, as

well as furniture dimension stock, landscape ties, pallet stock, posts, and firewood) was $242 million dollars. In 1987, sawmills processed approximately twice the volume of timber produced in Massachusetts (importing what they did not buy locally). While there are some very large assumptions in this calculation, it appears that the value added is on the order of $20 of primary product value for every $1 of raw timber sold. Therefore, if the MDC sells approximately 3 million board feet of timber in a year, at an average value on the stump of $100 per thousand board feet, it contributes the equivalent of $6 million to the Massachusetts primary wood products economy. To the extent that these primary products remain in Massachusetts to be converted by secondary industries into finished wood products, this state "value added" figure is many times higher.

For a discussion of the differences between the Division's watershed management silviculture and commercial uneven-aged management, see Supporting Appendices: Watershed Management and Uneven-aged Silviculture: A Comparison of Goals and Techniques.

c. Regeneration of the Quabbin Forest

The mortality rates in the maturing Quabbin watershed forest, as well as recurrent threats to the overstory, have strengthened the concern of Division managers regarding the regenerative ability of that forest. Regeneration serves to anchor soils following disturbances, resist damage from many disturbances (due to size and density), assimilate nutrients more rapidly than older vegetation, and shorten recovery times for reestablishing forests following disturbances. For these reasons, the ability of the watershed forest to regenerate continuously in the face of a wide variety of disturbances is considered critical to its ability to protect water quality.

During the decade since the last Quabbin Management Plan, the Division has completed a series of inventories and tests to document the condition of regeneration across the watershed. An initial survey was completed in 1988, when milacre plots were taken at each of 75 selected C.F.I. plots. This preliminary survey was followed in 1989 by a survey of 796 milacre plots located along transects throughout MDC holdings on the Quabbin watershed. The results of the 1989 survey were reported in a Division publication entitled "1989 Quabbin Forest Regeneration Study". Milacre sampling on transects was repeated in 1993. In addition, permanent fenced and unfenced 1/100th acre plots were established in Pelham, throughout the Western Drainages, and are remeasured each year for regeneration changes. Information on regeneration is also gathered from other research, including that by Dr. William Healy (U.S. Forest Service-Amherst) on the influence of deer on the forest understory.

In general, the analysis of the regeneration data collected shows consistently that although seedling establishment of all local species is adequate nearly everywhere, the development of these seedlings has been impaired, often severely, in areas where the populations of white-tailed deer regularly exceed the levels found in areas that are hunted. The 1989 survey concluded that regenerating areas where deer had not been hunted for nearly 50 years contained, on average, less than 15% as many young trees taller than browsing height (4.5 feet) as those areas that have been hunted. Furthermore, species diversity was lower in high deer areas, with preferred browse such as hemlock replaced by rapid-growing, less preferred species such as black birch. Generally speaking, white pine regeneration thrives in moderately browsed areas, in part because of the removal of hardwood competition by browsing.

Regeneration information was collected during the 1990 remeasurement of C.F.I. plots, from 10: 1/1000 acre plots systematically located from the plot center. The regeneration goal on the watershed, established in the 1991 "White-tailed Deer Impact Management Plan" is 2,000 stems greater than 4.5' in height per acre. The regeneration inventory on C.F.I. plots was conducted simply to determine the percentage of plots that were adequately regenerated, rather than to derive mean stem density per acre by species. Consequently, a maximum of two stems greater than one foot in height were recorded at each milacre plot. Where there were more than two stems within a plot, the two stems most likely to survive and grow were recorded. (Note that this relates to the fact that it is extremely unlikely, if not impossible, for more than two trees to survive to maturity within any given 1/1000 acre.)

On 1,790 milacre plots at C.F.I. plots, 47% of those in areas that are not hunted had no regeneration greater than one foot tall, while 97% of those from hunted areas had at least one stem greater than one foot tall. Hemlock, oak, and ash greater than one foot were present on fewer than 4% of the "not hunted" plots. In areas that are hunted, ash was still relatively scarce (92% of the hunted plots had no ash greater than one foot), but hemlock and oak greater than one foot were present on 47% and 61% of the plots, respectively. The results of the 1990 C.F.I. regeneration inventory are shown graphically in Figure 4.

Additional detail on the regeneration process in the Quabbin forest is included in this plan under the description of Forest Management, Section V.B.3.d., and in separate MDC reports.

2. Wildlife

a. Overview of Wildlife Community

Quabbin is considered to have rich and abundant wildlife. Its size, undeveloped character, protection and diversity of habitats result in conditions suitable for many species representing all major taxa.

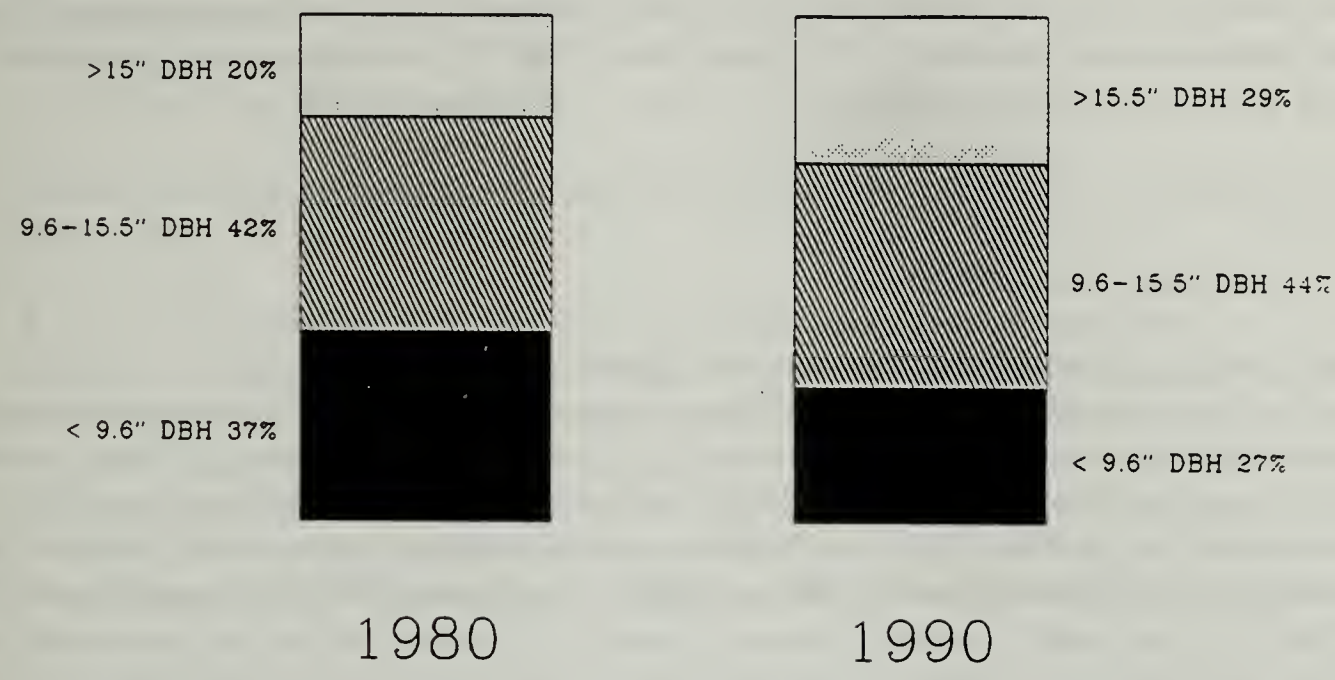
Abundance and distribution characteristics for individual wildlife species are strongly influenced by the distribution and suitability of habitats. Quabbin is predominantly forested, with only occasional non-forested habitats and is therefore dominated by those species that are adapted to forested habitats. Early successional wildlife species are more restricted in their ranges, occurring in and around the occasional clearings and beaver flowages on the watershed.

Water-based species (e.g., waterfowl, beaver, otter, loons, amphibians, etc.) are relatively common and well-distributed, both at the Reservoir and adjacent to the network of drainages and beaver ponds throughout the watershed. In recent years, surveys of vernal pools on the watershed have yielded information on a variety of herptiles.

Since the mid-1980's, the Division has conducted a variety of surveys to document and monitor the presence and status of various wildlife species on Quabbin. These include annual surveys of deer, beaver, breeding birds, Canada Geese, and Common Loons. Other species are surveyed on a less frequent basis (e.g., coyotes). Still others are monitored through the activities of other agencies

Figure 3:

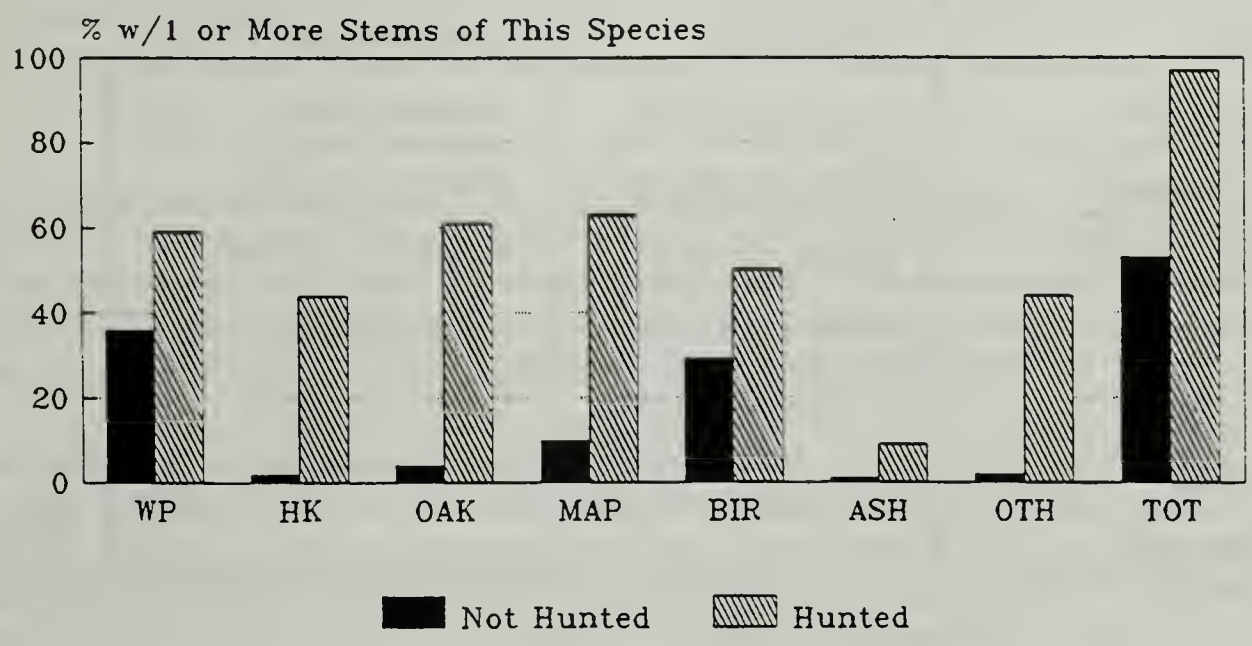
Diameter Distribution – Quabbin CFI
1980 versus 1990 – All plots combined



DBH = Diameter at Breast Height

Figure 4:

1990 CFI Regeneration
Not Hunted Plots vs. Hunted Plots
Regeneration >1' in Height



TOT=combined total all regeneration
1/100th acre plots

(e.g., the annual mid-winter eagle survey conducted by MDFW), researchers (e.g., porcupines, small mammals), or individuals (e.g., Christmas Bird Counts). The results of all of these activities are available to MDC, and contribute to the understanding of the composition of the Quabbin wildlife community.

Much is known about the wildlife community at Quabbin, but with the exception of birds, attempts to develop full species lists have not yet been completed (efforts to inventory butterflies, reptiles, and amphibians are occurring). It is likely that a fairly full complement of species that are indigenous to this region occur at Quabbin.

b. Rare Species and Habitats

Rare wildlife species and habitats occur throughout the Quabbin watershed. At least 27 species listed as "special concern" by the Massachusetts Natural Heritage and Endangered Species Program have been observed, or are known to breed at Quabbin (Table 6). Some of these occurrences are historical records only, or were associated with temporary habitat creation in the past. For example, reports of Sedge Wren, Henslow Sparrow, and Grasshopper Sparrow were linked to the extensive sand flats near Grave's Landing that resulted during times of very low water levels in the 1960's.

Table 6. Special Concern Wildlife Species Known to Occur at Quabbin.

MAMMALS:	**BIRDS:**	
S. Bog Lemming	Common Loon	Long-eared Owl
N. Water Shrew	Pied-billed Grebe	Short-eared Owl
REPTILES/AMPHIBIANS:	American Bittern	Sedge Wren
Spotted Turtle	Least Bittern	Loggerhead Shrike
Wood Turtle	Bald Eagle	Golden-winged Warbler
Eastern Box Turtle	Northern Harrier	Northern Parula
Jefferson Salamander	Sharp-shinned Hawk	Blackpoll Warbler
Marbled Salamander	Cooper's Hawk	Mourning Warbler
Spring Salamander	Peregrine Falcon	Grasshopper Sparrow
Four-toed Salamander	Common Moorhen	Henslow's Sparrow
Black Rat Snake		
Timber Rattlesnake		

Other occurrences of species not on the state special concern list, but nevertheless of interest, have also been recorded. For example:

- A number of sightings of Mountain Lions, Moose and Black Bear have been reported in recent years;
- Common Ravens now nest at several sites on the Reservation;
- Great-blue Heron rookeries exist on several stream drainages;
- The first nestings of Cerulean Warblers in the state have recently been documented at Quabbin;
- A Black Racer hibernaculum was recently discovered in a tunnel spoil pile;
- There are three Quabbin breeding locations of Worm-eating Warblers;
- There are three Quabbin breeding locations of the Acadian Flycatcher.

Several important wildlife habitats are also known to exist on the watershed. An historic Peregrine Falcon nest site exists on one of the steep slopes at Quabbin. Vernal pools containing special concern species are being discovered, and documented by yearly Division surveys. When the Reservoir level drops, extensive areas of exposed shoreline provide habitat for large numbers of shorebirds and other "open-land" species.

Most of the information on rare species and habitat occurrences on Quabbin has come from the casual observations and records of birders, hikers, Division employees and other users of the area. Until recently, few formal surveys have been conducted specifically to locate rare species or habitats. In the past few years however, vernal pool surveys, small mammal trapping and other focussed searches have resulted in a number of rare species discoveries. As these continue, it is anticipated that the list of known rare species and habitat occurrences on the watershed will continue to grow.

D. Cultural Resources

1. State of Knowledge

In reviewing the archaeological data of the Quabbin Watershed, one is impressed first with the number of prehistoric sites, and secondly with the poor quality of the data concerning the formation processes, and the behavior responsible for creating these sites. Unfortunately most of the sites in the former Swift River Valley and along its tributaries have been disturbed in one way or another, so there is little substantive information regarding prehistoric occupation in the area.

Predictions on archaeologically sensitive areas, and the expected type and range of prehistoric settlement in the Quabbin region can be drawn from the application of settlement theory to current land conditions. Currently, the Massachusetts Historical Commission (MHC) has records for more than seventy prehistoric sites on MDC's lands at Quabbin. While informative, this figure is artificially low. Although the MHC's records are the single most complete archaeological data bank in the state,

they represent but a small fraction of the actual number of sites that are known to avocational archaeologists and collectors. Indeed the majority of the sites currently recorded in the Quabbin Watershed were discovered by an artifact collector who discovered sites that were exposed when the waters of the reservoir were low.

2. Prehistoric Overview

Existing archaeological evidence suggests that Paleo Indian hunters and gatherers had reached the Swift River drainage by 9,500 to 12,000 years ago. By about 9,500 years ago the warming climate had created an environment in southern New England that supported a mixed pine-hardwood forest. Three archaeological sites indicate that human occupation of the area continued during the *Early Archaic period* (ca. 9,500 to 8,000 years ago).

During the *Middle Archaic period* (ca. 8,000 - 6,000 years ago) climatic and biotic changes continued and the mixed deciduous forests of southern New England were becoming established. Significantly, the present migratory patterns of many fish and birds are believed to have become established at this time (Dincauze 1974). During the spring those rivers, streams and ponds utilized by anadromous fish for spawning would have been particularly important for fishing. Groups are likely to have traveled considerable distances to camp adjacent to falls and rapids where they could easily trap and spear the salmon, herring, shad and alewives. This subsistence strategy persisted throughout prehistory. Evidence of Native American occupation of the Quabbin region during *Middle Archaic* times comes from four sites.

At least twenty-four sites within the Quabbin Watershed have yielded diagnostic *Late Archaic period* (ca. 6,000 to 3,000 years ago) materials. The marked increase in site frequencies and densities is consistent with findings throughout most of southern New England, and may document a population increase during this period. Each of the three traditions -- the Laurentian, Susquehanna and Small Stemmed Traditions -- are well represented in the archaeological record of local sites. Terminal Archaic activity (ca. 3,000 - 2,500 years ago) is suggested at three sites, including a steatite quarry.

During the *Early, Middle* and *Late Woodland* periods (3,000 - 450 years ago) Native Americans continued to occupy the Swift River drainage. Evidence comes from five sites from each period. Regionally, horticulture was introduced during the Early Woodland and small gardens may have been planted in clearings located on the fertile alluvial terraces next to the Swift River and its larger tributaries.

3. Interpretation of the Archaeological Record and Implications for Management

Analysis of artifacts from local sites reveals a pattern of multiple, recurrent occupation. Few sites have yielded artifacts from a single cultural/temporal period. Instead, artifacts from several periods have typically been recovered from sites. This suggests that some particularly well-sited locations were occupied, or otherwise utilized, more than once. Recurrent, though intermittent, occupation of a single site, sometimes over a period of several thousand years, appears to have been the prevalent pattern of prehistoric site development in this region.

Small groups, probably based on kinship, would have found the uplands most attractive for short term occupation. Settlement is likely to have occurred on virtually any elevated, level and well

drained surface that was located immediately adjacent to sources of fresh water, including the headwaters of ephemeral streams, springs, and small wetlands and ponds. Rockshelters and other natural overhangs, and locations with southerly exposures would also have been utilized.

4. Historic Sites

In addition to prehistoric archaeological sites, Quabbin watershed contains a wealth of historic archaeological sites. Since 1736, with the grant of 1,000 acres, colonists have been drawn to the Swift Valley by its water resources and by the valley's rich alluvial soils. By 1822 Prescott, Enfield, Dana and Greenwich had a combined population of 3,000 people and they were incorporated as towns. Over the ensuing century, these communities prospered but retained their small size and rural characteristics.

With the passage of the Swift River Act in 1927, the four Swift River communities were disincorporated, and their lands were purchased by the Commonwealth as plans for the Quabbin Reservoir became finalized. Together with additional land from adjacent towns, the state acquired a total of 80,433 acres by 1938. During this time, 650 houses and 450 structures were removed from the valley. Many of the superstructures of these buildings were relocated to other communities, and some had their cellar holes filled, leaving little or no trace of their existence. The filling was especially prevalent in Prescott. However, the foundations from farmsteads and mills in the other communities were often left intact. Also scattered across the landscape is a maze of stone walls, farm roads, wells and other cisterns, and refuse piles that further document the historic land use of the Swift Valley. Today, these remnants of the valley's historic past represent a valuable cultural resource, and the Division accepts the responsibility and challenge to preserve them.

III. Research-based Principles Guiding Watershed Management

The purpose of this section is to identify various principles of watershed management that form the basis for the specific goals and implementation objectives for management of the Quabbin watershed lands during the period covered by the plan. These principles were distilled from the comprehensive literature review included in the SUPPORTING APPENDICES for this plan, which summarizes the findings from approximately 350 watershed, forestry, and wildlife management papers that were reviewed by Division staff. Relevant information from this review is also incorporated in the comparison of three watershed forest management alternatives described in Section V below.

Watershed Management Principles

Watershed Protection

• Forested watersheds generally yield higher quality water than non-forested cover types. Urban, suburban and agricultural land uses all contribute in some way to lowered water quality.

• Uncontrolled human activities on water supply watersheds represent a major source of potential contamination. Efficient and effective water quality protection on both filtered and unfiltered water supplies requires control over human activities.

• Watershed cover conditions differ in their regulation of certain nutrients (esp. nitrates); the best regulation of nutrients is provided by vigorously growing forest that is fully occupying all watershed sites.

• Fire protection, police surveillance, water sampling, and other watershed management activities, including forest management, all depend upon an adequate, well-maintained watershed road system.

• The proper management and protection of wetland and riparian zones is a critical component of watershed protection.

Water Yields

• Water yields are influenced by precipitation amounts, site conditions (such as slope, aspect, and soils) and the intensity and type of watershed cover management.

• Water yields are affected directly by evapotranspiration rates of the watershed cover. Therefore, management activities that result in decreased evapotranspiration also result in increased water yield.

• Intensive, even-aged management of forested watersheds provides consistently greater water yields than either uneven-aged management or the absence of active management.

• Water yields decrease as young forests grow. As forests become more open, water yields increase.

Watershed Forest Management: General

• Watershed forests can be managed in a way that provides significant benefits to long-term water quality protection, while minimizing adverse impacts during management operations.

• With proper road location and maintenance, and proper planning and supervision of silvicultural activities, potential negative tributary water quality impacts (including turbidity, nutrients, and streamwater temperature) from forest management can be minimized or eliminated.

• Stands developed through uneven-aged methods will continually include some younger, shorter trees. Older trees in these stands develop stronger, more tapered stems than those grown in dense, even-aged stands. Strongly tapered trees sustain less damage from wind, and the younger component in uneven-aged stands enable them to recover from disturbance more quickly than maturing even-aged stands, thus improving their relative long-term water quality protection.

Watershed Forest Management: Disturbance Impacts

• Overstory blowdown can temporarily increase erosion and nutrient leaching, by disturbing soils, increasing decomposition rates, and causing a setback in biomass accumulation rates.

• Severe forest fire can significantly reduce soil infiltration, thereby increasing overland flow of water, sediments, and nutrients.

• A forest that is diverse in age structure and species composition limits the impacts of age- and species-specific disturbances.

• Forests with advance regeneration in the understory will recover more quickly from disturbances to the forest overstory than will forests with poor understory development.

• Younger, shorter trees will sustain less damage from severe wind storms than taller, older trees, due both to their lower tendency to "catch" the wind, and to stem flexibility.

• While tightly grown, "aerodynamically smooth" *stands* may deflect wind better than those that are "aerodynamically rough", *individual trees* that have been grown in more open stands will develop strongly tapered stems that resist wind better than the non-tapered stems of trees grown in tight stands.

• Runoff from infrequent, large storms with associated intense rains and flood waters account for a much of the annual particulate, sediment, and dissolved nutrient outputs from watersheds.

Air Pollution Impacts

• Forests serve as "sinks" for various environmental pollutants, retaining them and slowing their movement into water supplies. A tall, dense, and layered forest serves this function more effectively than a short, sparse forest.

• Environmental pollution has been linked to general forest decline, which increases the susceptibility of those forests to insects, diseases and other impacts.

• Actively growing forests with a diversity of species and sizes may help buffer the impacts of acid precipitation on water supplies.

• Air pollution contributes to nitrogen saturation of forest ecosystems. Nitrogen saturation can cause elevated nitrate, aluminum, and hydrogen levels in streams and losses of cation bases from soils. These impacts can be compounded by acid precipitation and ozone pollution, and ameliorated by the accumulation of biomass and nutrients in an actively growing forest.

Wildlife Impacts

• Wildlife populations can have significant impacts on both habitat and water quality conditions.

• The composition of wildlife communities is dictated by various factors - chief among them are habitat conditions, landscape characteristics, and mortality factors.

• Land management practices that change habitat conditions will result in changes in the wildlife community.

IV. Watershed Management Goals

The watershed management goals of the DWM, for land management, are to:

- PROVIDE THE BEST POSSIBLE COVER THROUGHOUT THE WATERSHED FOR PROTECTING RESERVOIR WATER QUALITY, AND

- MINIMIZE OR MITIGATE BOTH POINT AND NON-POINT SOURCES OF WATER POLLUTION.

Within this land management plan, the vast majority of the Division's effort to achieve these goals is focussed on lands owned by the MDC within the watershed. However, the plan also includes a land acquisition program aimed at securing additional control over sensitive watershed lands, as well as programs that educate and provide technical assistance to owners of non-MDC watershed lands in order to expand watershed protection practices to these lands.

The following sections identify goals for the main areas addressed in this plan (i.e., Water Quality and Yields; Land Protection; Forest Management; Wildlife Management; and Cultural Resource Protection).

A. Water Quality and Yield Goals

1. Quality

The short and long-term goals of the Division of Watershed Management regarding water quality are to:

- CONTINUALLY MEET THE MASSACHUSETTS SURFACE WATER QUALITY STANDARDS FOR CLASS A WATERS AND REGULATIONS FOR SOURCE WATER QUALITY RESULTING FROM THE U:S. E.P.A. SAFE DRINKING WATER ACT; AND

- MINIMIZE THE LONG-TERM CUMULATIVE EXPORT OF NUTRIENTS AND SEDIMENTS TO THE RESERVOIR; IN ORDER TO

- PROVIDE A SAFE AND SUFFICIENT SUPPLY OF WATER FOR PRESENT AND FUTURE GENERATIONS.

The long-term quality of water in the tributaries that flow into the reservoir is a function of geology, soils, topography, vegetation, weather (especially infrequent major floods, hurricanes, fires, etc.), human impacts and wildlife activity. Human and wildlife impacts can also impact water quality over the short-term. The effect of vegetation upon water quality varies with physical basin characteristics, and becomes an important factor in the long-term when the impacts of large, infrequent natural disturbances must be considered. Of these factors, MDC management can only affect vegetation and human and wildlife impacts.

It is not within the scope of this plan to include evaluations of current, short-term water quality in the Quabbin Reservoir or its tributaries, except where this is affected by land management or wildlife populations. Human impacts, especially on private lands, that directly and immediately

affect the quality of Quabbin water are addressed in the Watershed Protection Plan for Quabbin Reservoir (MDC/MWRA 1991) and in various water quality sampling reports and sanitary survey reports (see especially Bishop 1992). High potential threats to water quality at Quabbin include: septic systems, recreational activities on MDC lands, transportation-related releases, and animal populations on MDC lands (MDC/MWRA 1991).

The water quality parameters of primary concern in this plan are turbidity, nutrient loads, total organic carbon, and pathogens associated with wildlife populations. It is always the Division's preference to maintain tributary water quality as high as possible and in that light, any increases of monitored parameters may be of concern. The Division continues to monitor and model the water quality impacts of both random (natural) and deliberate events, in an effort to measure the long-term costs and benefits of management activities.

Presently, MDC Environmental Quality staff monitor source water quality on 15 Quabbin watershed sampling stations on a regular basis and analyze water for up to 27 parameters, depending upon the site. The Division is also involved in special sampling projects focused on specific impacts such as bacterial contamination from gulls, stormwater contamination, nutrient influences, *Giardia* and *Cryptosporidium* contamination on specific tributaries, and identification of contamination sources where routine sampling shows water quality degradation. These special sampling programs have been conducted at 61 monitoring sites at Quabbin.

It is the intent of this plan to help maintain long-term MDC water quality goals through the proactive management of watershed cover, the acquisition of additional lands in critical areas, and the management of wildlife populations that potentially threaten water quality.

2. Yield

• THE DIVISION'S GOAL FOR THIS MANAGEMENT PERIOD IS TO PREVENT DECLINES IN WATER YIELDS.

Recent successes in water conservation and leak detection within the MWRA communities have resulted in dramatic declines in demands on the MDC/MWRA water supply system. The increased emphasis on water quality protection has led to the decision to promote diverse forest cover on most of the watershed. This decision limits the opportunities for large water yield increases, since such increases could only be achieved through substantial reductions in forest cover. Starting with a mature forest cover, the forest management alternative selected in Section V.B.2. would tend to increase water yields, due to reductions in overstory stocking and related evapotranspiration. However, it is difficult to predict the confounding influence of a recovering understory - the result of reduced deer browsing impacts. It is a general goal of this plan to prevent declines in water yields on the watershed, but not to aggressively increase water yields, due to concerns about the water quality impacts that would occur from this type of program and the increases of nutrients that would be associated with significantly higher water yields.

The relationship between forest cover and water yields varies with the physical characteristics of a basin. Forests affect water yields through increases in evapotranspiration and evaporation and changes in the flow path of precipitation. Forests have a more pronounced impact on water yields in water rich and riparian areas and on north-facing slopes. In general, dense forest cover yields less water than more open forest, but this relationship varies greatly by site. While forest management

priorities will be set for the primary goal of water quality protection, the secondary goal of water yield enhancement will be pursued when it is consistent with the primary goal and on sites where it is achieved in the most efficient manner (north-facing slopes, etc.).

In order to assess progress toward the above goal, the Division will utilize its research budget (see Section VI.) to select and apply a watershed computer model appropriate for this region and given Division objectives. This model will be used to set priorities for land management activities. For example, water yields from the programs adopted in this plan will be estimated via the model, in order to improve water yields through specific modifications in silviculture, if necessary.

B. Land Protection Goals

MDC's goals for land protection are to:

- LIMIT LAND USES ON THE WATERSHED TO THOSE THAT DO NOT THREATEN WATER QUALITY; AND

- PROVIDE CONTROL OVER NON-FOREST LAND USE (E.G., ROADS), THE EFFECTS OF NATURAL EVENTS (E.G., FIRE), AND HUMAN ACTIVITIES THAT THREATEN WATER OR OTHER NATURAL RESOURCES.

An effective watershed management program must address the control of both human-caused and natural impacts on watershed integrity and water quality. Much of this control on MDC watersheds is achieved through the programs and activities of the Environmental Quality section, and thus is not directly addressed in this plan. However, various aspects of MDC's Land Management program do directly involve land protection functions.

Control over harmful activities on the Quabbin watershed is best achieved when the Commonwealth has actual ownership, or other direct control over allowable activities on the land. Thus, MDC has an active land acquisition program geared towards acquiring ownership of, or other rights on, key parcels on the watershed - primarily those near the reservoir and its principal tributaries and wetlands. Once acquired, these lands can then be managed to establish and maintain optimal cover types that provide for the long-term protection of water quality. In some cases, this may involve converting open land to forested cover.

The location, marking and maintenance of the boundaries of MDC watershed lands are also important land protection activities, since clear boundaries allow for better control over illegal activities that could threaten watershed integrity. Effective resolution of boundary encroachments is also an integral part of boundary maintenance.

The control of potentially harmful activities on watershed lands requires a human presence on those lands, both to identify and locate those activities, and to provide effective enforcement of rules and regulations. This presence is provided both by MDC personnel, and the Massachusetts State Police. This presence allows for the timely discovery and resolution of potentially harmful human activities (e.g., illegal dumping) and natural events (e.g., fires) on the watershed.

Effective monitoring and control also depends on a good road system that allows quick access to all parts of the watershed lands. However, since gravel roads also constitute a source of erosion and sedimentation into streams and water bodies, watershed road maintenance must be done in ways that minimize these potential adverse impacts.

Finally, land protection goals can sometimes be best served through the designation of "Areas of Special Management Restrictions", on which management and other human activities are restricted. Such designations are especially appropriate on sites where the topography, hydrology, vegetation or other characteristics limit the potential benefits of active management.

C. Forest Management Goals

The Division's goals for forest management are to:

- PROVIDE A VIGOROUS FOREST COVER, DIVERSE IN SPECIES COMPOSITION AND TREE SIZES, ACROSS THE VAST MAJORITY OF THE WATERSHED;

- MAINTAIN FOREST COVER THAT BALANCES ACTIVE GROWTH AND NUTRIENT ASSIMILATION, DENSE FILTRATION, TEMPERATURE REGULATION, AND ACTIVE REPRODUCTION;

- RETAIN THIS FOREST COVER BY EXPEDIENTLY RE-ESTABLISHING AND MAINTAINING ADEQUATE FOREST REGENERATION ACROSS MDC QUABBIN LANDS;

- ENHANCE AND MAINTAIN THE ABILITY OF THE WATERSHED FOREST TO BOTH RESIST AND RECOVER FROM DISTURBANCE;

- PREVENT EROSION OF SEDIMENTS AND NUTRIENTS FROM THE WATERSHED FOREST, AND PROVIDE FOR ACTIVE ASSIMILATION OF AVAILABLE NUTRIENTS;

- LIMIT THE EFFECTS OF HUMAN-CAUSED AIR POLLUTION BY PROVIDING COVER THAT FILTERS AND/OR BUFFERS POLLUTANTS;

- DEVELOP A LOW-MAINTENANCE WATERSHED FOREST, WHICH PROVIDES LONG-TERM WATER QUALITY PROTECTION WITH MINIMAL INTERVENTION;

- CONDUCT ANY FOREST MANAGEMENT ACTIVITY SUCH THAT THE RESULTING BENEFITS OUTWEIGH ANY POTENTIAL NEGATIVE IMPACTS;

- SALVAGE DEAD AND DOWNED MATERIAL IN AREAS WHERE THIS SALVAGE WILL REDUCE THE THREATS OF FIRE OR NUTRIENT TRANSPORT, AND LIMIT THE NEED FOR SALVAGE, THROUGH DELIBERATE MANAGEMENT PRACTICES AIMED AT REDUCING THE LIKELIHOOD OF DAMAGE.

The Division has determined that a diverse, vigorous forest cover should be maintained on the vast majority of its holdings, due to the unequaled water quality protection this cover provides. The chief value of this tree cover is to act as a layered filter for purifying the water that passes through it. The tall crowns of the forest overstory add depth to this filter and provide temperature regulation of

surface, ground, and stream waters. Those portions of the forest that are actively growing and assimilating available nutrients limit the export of these nutrients to the reservoir. The forest understory provides uninterrupted recovery from overstory losses. The layers of the forest overstory canopy, the forest understory, the vegetative ground cover, and the thick organic mat of decomposing matter on the forest floor, as well as root systems interspersed within the mineral soil below, all work in concert to produce water of high quality.

In order to retain forest cover through the variety of disturbances that affect that cover, it is a Division goal to expediently re-establish and retain adequate forest regeneration across the watershed. While the specifics of "adequate regeneration" are addressed later in the plan, the Division believes it is a prudent goal to steadily maintain well-distributed reproduction, so that the forest is capable of quickly recovering from disturbance. In simple terms, the understory represents a "reserve forest", a back-up to cover the eventuality of overstory losses.

A primary goal of Quabbin forest management is to develop a mixture of forest layers, including well-distributed regeneration, in order to reduce the susceptibility of the forest to catastrophic wind damage. While hurricanes are potentially the most disruptive disturbance facing the Quabbin watershed forest, the more frequent occurrence of less dramatic disturbances is also of concern to managers. These include the effects of air pollution, insects and diseases, and changes brought about by smaller scale weather events such as localized windstorms and heavy snow or ice storms. A forest that is diverse in species composition and multi-layered will resist natural impacts and human-caused pollution because these impacts tend to be species and/or size/age specific. Thus, the Division's forest management will "condition" the forest to be able to recover quickly from both localized, endemic disturbances and wide-spread, catastrophic events, in part by maintaining diversity.

Producing and retaining a multi-layered forest cover addresses the Division goal to protect the tributaries from undesirable chemical, nutrient, and sediment inputs in a variety of ways. First, this cover reduces the erosion potential of precipitation and minimizes damaging overland runoff. The various layers of the forest also serve to buffer chemical impacts to water quality by maximizing water contact time with vegetation and soil components. Through the process of evapotranspiration, forests act as water yield "regulators, moderating the potential water yields of watersheds and thereby regulating the loss of nutrients, minerals, and natural elements from the watersheds to the water supply below. Forests that are growing actively accumulate nutrients from the soil, reducing their export to tributaries. Finally, forests likely play an important role in reducing the effects of human-caused pollution such as acid precipitation, heavy metals, and other environmental pollutants by both buffering impacts and by acting as "sinks" for certain pollutants such as lead.

The Division has concluded that the diversity of species appropriate for watershed management purposes should reflect the basic variation in the landscape and natural site conditions (e.g. soils, topography, water, aspect, slope) found at Quabbin. While a range of tree species may be adequately suited to a given site, the management of species that are unsuited to the site (for example upland species on wetland sites), does not provide optimal watershed protection. Trees growing off of the sites to which they are physiologically most suited are more susceptible to disease, wind, and other environmental impacts (the declining vigor of many red pine plantations on wet soils demonstrates this). In general, species that are well-suited to their sites will grow vigorously over long periods of time, reducing the frequency of mortality and salvage operations. This principle is inherent in the goal of the Division to create a watershed protection forest which requires a minimum of maintenance to achieve its function.

It is a Division goal that any forest management activities on the watershed be conducted in such a way that even if no natural disturbances affect an area, the overall benefits to the resource from the activity still outweigh the potential impacts resulting from the activity itself. All activities have both long and short-term consequences. In assessing the net costs or benefits of forest management activities, the Division considers both immediate and future impacts. For example, activities such as the cutting and/or removal of trees to deliberately regenerate an area must be controlled such that any short term negative water quality impacts from harvesting will be less than the long term benefits derived from diversifying the forest cover.

When major losses of forest trees occur naturally, it is a goal of the Division to salvage dead and downed materials when such salvage will reduce nutrient export and will decrease the risk of catastrophic fires. Further, by reducing the likelihood of damage requiring salvage, and by maintaining good access to forest areas susceptible to damage, forest management should reduce the difficulty and potential water quality threat of these salvage operations.

Section V.E. in this management plan discusses cumulative sub-basin analysis, one result of which will be to designate secondary use areas, where forest cover of the type described above is not as critical for water quality protection. For instance, these might include areas that are relatively flat, far from any tributary, and sheltered from severe storms. The Division will consider maintaining cover types or conducting management practices on these areas that are different from the standards described above. For example, these areas might allow the maintenance of more extensive early successional habitat to support specific wildlife.

D. Wildlife Management Goals

The Division's decision to maintain forest cover on the vast majority of its holdings, largely pre-determines the nature of wildlife habitat conditions on most of the Quabbin watershed. Active wildlife habitat management will occur on a very limited basis on these lands, although it may occur to a greater extent on lands designated for secondary uses. The main focus of the wildlife program at Quabbin is to protect important wildlife and their habitats, while minimizing adverse wildlife impacts on other watershed resources. Accordingly, the goals of the wildlife management program are to:

- MITIGATE POTENTIALLY ADVERSE IMPACTS OF WILDLIFE ON WATER QUALITY, INFRASTRUCTURE, AND OTHER WATERSHED RESOURCES;

- PROTECT UNCOMMON, RARE, AND OTHERWISE SIGNIFICANT WILDLIFE SPECIES AND HABITATS WHEREVER THEY EXIST ON MDC LANDS;

- ASSESS AND MITIGATE IMPACTS OF WATERSHED MANAGEMENT ACTIVITIES ON WILDLIFE THROUGH A PROCESS OF NOTIFICATION, SITE VISITS, REVIEW OF RECORDS AND LITERATURE, AND RECOMMENDATIONS TO APPROPRIATE MANAGEMENT STAFF; AND

- ACTIVELY MANAGE FOR SELECTED WILDLIFE SPECIES THAT ARE CONSIDERED TO BE UNCOMMON, RARE, OR UNIQUE ON A REGIONAL OR STATE-WIDE BASIS.

The wildlife community composition on MDC watersheds will be largely determined by the habitat that is provided by the forest conditions the Division strives to achieve. Active wildlife habitat

management will not be a major part of this plan. However, throughout its land management activities, the Division strives to identify and protect important wildlife species and habitats from adverse impacts related to that management. This is accomplished mainly through inventory and survey work to locate rare species and habitats, coordination with the Massachusetts Endangered Species and Natural Heritage Program, and through management guidelines and BMP's to minimize impacts on those resources.

Due to the potential impacts some wildlife species can have on water quality, the focus of much of the wildlife program at Quabbin must be on mitigating those impacts where and when they occur. Such impacts range from the potential contamination of the water supply by roosting gulls, to the undermining of dam integrity by burrowing mammals.

Just as wildlife activity can impact watershed operations or resources, so too can management operations impact wildlife. Thus, another goal of the Division's watershed management program is to assess the likely impacts of land management activities on Quabbin's wildlife community, and to minimize adverse impacts. This is mainly accomplished through an in-house review process (Section V.B.6.) for all planned management operations.

The final wildlife goal relates to the active habitat management of portions of the watershed (identified in the basin analysis process described in Section V.E.) for selected wildlife species. This goal goes beyond the protection of existing rare species and habitats to include proactive habitat management for wildlife species that are in need of special management attention regionally.

E. Cultural Resource Protection Goals

The Division's goals for cultural resource protection include:

- IDENTIFY SIGNIFICANT CULTURAL RESOURCES ON WATERSHED LANDS; AND
- PREVENT DEGRADATION OF CULTURAL SITES AND RESOURCES.

Cultural resources are fragile and non-renewable. Once destroyed they are gone forever; they cannot be regrown, rebuilt or repaired. Similar to endangered and threatened species of flora and fauna, the fragility of these resources places a value on them that is difficult to calculate.

Preservation legislation, as well as MDC's Cultural Resource Management program, are designed to ensure that future generations will have the opportunity to understand, appreciate, and learn about the past. The Division is concerned with locating and assessing the condition of both historic and prehistoric cultural resources, and generating plans for protecting those resources that are considered unique or are otherwise significant.

The Division's Cultural Resource Management Program at Quabbin is adapted from a broader plan that was developed for the agency as a whole in 1990. The original plan was articulated in draft form in an MDC document entitled *Cultural Resource Management Plan: Volume One Management Policies, Operating Procedures & Organization*, by Chief MDC Archaeologist Thomas F. Mahlstedt, 1990. The agency plan has been modified to address the specific requirements and nature of the resources contained on the Division's watersheds lands under its jurisdiction.

V. 1995-2004 Management Plan Objectives and Methods

The sections below detail the conversion of the goals specified for each of the Quabbin watershed land management programs into objectives for the ten year management period and methods for achieving these objectives. The basin analysis described at the end of this section is one of the methods the Division will use to translate its watershed management goals into specific objectives for specific areas.

A. Land Protection

1. Land Acquisition: Summary of Objectives for Quabbin Watershed for the Decade

a. 1985-94 Land Acquisition Program Objectives and Accomplishments

1) Program History

From the completion of the Quabbin Reservoir Project (in 1938) to the mid 1980's, MDC completed only sporadic land acquisitions, generally triggered only when an especially critical parcel was endangered by development. The current Watershed Land Acquisition Program began on the Quabbin with several purchases in 1987. Since then, 2,167 acres have been purchased by MDC on the Quabbin watershed. The passage of the 1986 SDWA Amendment Regulations combined with the extensive building boom of the 1980's, were the key driving forces behind the acquisition program. Regulations that clearly and specifically linked land ownership and management to water supply protection, together with an imminent threat to critical watershed lands, brought the need for this program into sharp focus.

2) Program Goals and Accomplishments

The 1987 Open Space Bond Issue (Section 3 of Chapter 564, Acts of 1987) established a 30 million dollar account under the Executive Office of Environmental Affairs to purchase property in the Quabbin, Ware, and Wachusett watersheds for "the protection of the water resources of the Commonwealth". The General Court delegated responsibility for expending these funds to the MDC and the DFW.

In joint meetings between the MDC and the DFW, it was agreed that water supply protection was the first priority in the expenditure of these funds. Because DFW's chief mandates are geared towards wildlife protection and enhancement, lands that protected water and wildlife would be chosen, where possible. Within the goal of protecting water supply, the following criteria were used in prioritizing parcels for acquisition under the 1987 Open Space Bond Issue:

- Lands adjacent to major reservoirs and tributaries, especially those threatened by development,
- Lands in important tributary aquifers, especially those threatened by development,
- Lands in important tributary wetlands, not included above,

- Lands adjacent to MDC/DFW or other public lands within the watersheds,

- Lands that make management of existing MDC/DFW ownerships more efficient through improved access, reduction of boundaries, consolidation of parcels, and prevention of illegal access to MDC/DFW lands, and

- Lands valuable for wildlife habitat, scenic amenities, and open space.

The 1987 MDC Land Acquisition Plan for all watersheds listed a total of 14,102 acres for acquisition at an estimated cost of $41,097,400. The plan estimated that 8,800 acres could be acquired with an allotment of $30,000,000. It was anticipated in the 1987 Land Acquisition Plan that 1,700 acres would be purchased on the Quabbin Watershed; that goal was exceeded in 1993 (Table 7). It should be noted here that by Commonwealth law, the MWRA makes payments in lieu of taxes (PILOT) to towns in which MDC owns land. In 1993, these PILOT's totaled $663,017 to the 10 Quabbin watershed communities in which MDC owns land.

The passage of the Watershed Protection Act (WPA) (Chapter 36, acts of 1992) included a land acquisition bond totalling 135 million dollars with a mandated spending rate of a total of 8 million dollars per year for the Quabbin, Ware River, and Wachusett watersheds. MDC recently completed a land parcel selection mapping model for the Wachusett watershed, utilizing a Geographic Information System (GIS), in order to list priorities for the expenditure of the 135 million dollar bond. This model is based upon an updated set of parcel selection criteria. The main focus of the WPA bond spending will be the Wachusett watershed.

Table 7. Land purchases on Quabbin Watershed since 1987 (exclusive of DFW purchases).

FISCAL YEAR	# PARCELS	ACRES	COST
1987	4	291.6	$136,500
1988	1	77	73,000
1989	2	104.5	66,000
1990	7	593.9	683,800
1991	10	346.2	536,850
1992	6	203	469,310
1993	8	133.9	333,500
1994	8	410.4	1,063,000
1995	2	137.1	460,000
TOTALS	46	2,160.5	$ 3,821,960 ($1663/acre)

b. Land Acquisition Goals for 1993 and Beyond

Division staff feel that non-point source pollution is likely to be the largest future pollution source within the Quabbin watershed. This type of diffuse pollution (largely manifested in turbidity, nutrient loads, and low levels of organics and metals) is best prevented and mitigated through protection of key undisturbed drainage lands and is a strong argument for the future value of a well-designed land acquisition program.

The Quabbin Reservoir currently has a waiver from building a filtration plant from EPA and the Massachusetts DEP. The 1986 Safe Drinking Water Act Amendment Regulations relative to this waiver note that a watershed should be owned by the water purveyor or that agreements or regulations focused on private lands should be geared at adequately restricting activities or negative land uses.

At this time, approximately 2.8 million dollars is earmarked for targeted parcels on the Quabbin Watershed (Table 8). This acreage is primarily comprised of parcels along tributaries flowing directly into the northern reaches of the reservoir (i.e., Hop Brook in New Salem, West Branch Swift River in Wendell, Rocky Run in Shutesbury, Middle Branch Swift River in Orange, and Fever Brook in Petersham).

Table 8: Quabbin Watershed - Land Acquisition: 1995 - 2004

TOWN	ACRES	ESTIMATED COST
NEW SALEM	400	$900,000
PETERSHAM	450	850,000
SHUTESBURY	250	475,000
WENDELL	220	365,000
ORANGE	130	260,000
TOTALS	1,450	$2,850,000

The Division is undertaking an evaluation of optimal ways to spend the remaining monies in the Watershed Protection Act bond. This process will include rating of all undeveloped land within the three watersheds utilizing general criteria for purchasing land in the Act and more specific criteria outlined in the Supporting Appendices: Land Acquisition. This evaluation will involve computer modeling and mapping and will be completed during fiscal 1995. Once this evaluation is completed, the above estimates may be revised.

2. Technical Assistance to Private Forest Landowners

As described in Section II.A., almost 29,000 acres within the Quabbin watershed are "unprotected", privately-owned forestland. This figure does not include forest lands protected by

various private organizations in the Quabbin watershed. The Division plans to pursue acquisition of approximately 1,450 acres of the most critical parcels of this unprotected private land on the Quabbin watershed during the next decade. While there are no current plans to purchase the remaining lands in this category, activities on these lands are still of concern from an overall watershed protection standpoint. For example, the 1991 Watershed Protection Plan for Quabbin Watershed outlined several threats from land that is converted from forest land to developed land. Thus, a program of land protection through technical assistance to encourage the maintenance of these lands in forest cover seems well justified.

The Watershed Protection Plan rated the threat from logging on private watershed lands to be moderate to high. In addition to keeping lands in forest, this program will also strive to reduce impacts to the watershed from forest cutting on private lands, as there is a substantial amount of forest cutting occurring on these lands. For example, for Fiscal Year 1990, the Division completed forest management on only 290 acres on the watershed, while 13 operations occurred on 665 acres of private forest land.

In 1992, as part of this landowner education program, MDC established a "Stewardship Demonstration Forest" on 200 acres of forest adjacent to the Quabbin Visitor Center. This project is being done with the cooperation of the Massachusetts Association of Professional Foresters, the Massachusetts Forestry Association (a landowners group), and the Massachusetts Wood Producers Association. The project is part of the Department of Environmental Management's Massachusetts Forest Stewardship Program, which encourages landowners with many different objectives to become active stewards and to strengthen their desire to keep land in forest cover. On the demonstration forest, a self-guided trail leads visitors through a variety of stops that highlight best management practices for watershed, forest, and wildlife management.

MDC has also begun a one year pilot program of direct technical assistance to forest landowners at the Wachusett Reservoir watershed, where nearly 50,000 acres of unprotected forest lands exist. MDC recently hired a Private Lands Forester, with funding provided jointly by MDC and the U.S.D.A. Forest Service (in conjunction with DEM). The need for a Private Lands Forester has been noted in the past two Quabbin forest management plans. This forester will assist DEM foresters in administering M.G.L. Chapter 132, (the Forest Cutting Practices Act) specifically for the Wachusett watershed. In addition, duties will include outreach to private landowners to encourage land protection through programs such as M.G.L. Chapter 61 (Forest Tax Law) and the Massachusetts Stewardship Program. The Division will also encourage general use of its Best Management Practices for forestry operations on watersheds, as is recommended in the 1991 Watershed Protection Plan for both the Quabbin and Wachusett watersheds. The Private Lands Forester will encourage private land owners to manage their forests and wildlife to meet watershed-wide goals, looking beyond their individual property boundaries and designing management strategies that address the issues of the larger ecosystem.

In order to increase landowner participation in Chapter 61 and the Stewardship programs, MDC will consider contracting to hire private consultant foresters to complete forest management plans for landowners wishing to gain entry into these programs. In FY 95, $25,000 will be dedicated to completing plans for approximately 2,000 acres of private forest land. In addition, MDC will investigate the possibility of expending $15,000 in FY 95 to pay the 25% of cost-sharing not covered by the Stewardship Program for practices that benefit the watershed such as tree planting and erosion control on roads.

The Private Lands Forester will work closely with the Land Acquisition Coordinator so that lands that should be added to acquisition lists (due to imminent development, etc.) can be more easily identified. The Land Acquisition Coordinator can also direct landowners with a strong aversion to selling land to the MDC to the Private Lands Forester, so that intermediate protection measures (Chapter 61 or Stewardship) can be utilized.

A related alternative to the purchase of land is the utilization of Conservation Restriction purchases to prevent development while leaving land ownership in the current hands. For example, MDC currently holds conservation restrictions on more than 575 acres in the Quabbin watershed. The Private Lands Forester will work directly with the Land Acquisition Coordinator to identify opportunities for CR's. It is important to note, however, that MDC experience with CR's has shown that CR acquisition costs are often nearly the same as fee simple acquisition, and somewhat less desirable in that they require regular monitoring to assure compliance with the restriction specifics and with general watershed protection standards.

Pending successful results of its FY 95 program, MDC hopes to hire an additional Private Lands Forester for the Quabbin and Ware River watersheds in FY 96.

3. Boundaries

MDC property boundaries are the " front line" of watershed protection, in that they are immediately adjacent to private land on which MDC's watershed protection principles may or may not be followed. While the Watershed Protection Act has improved the enforceable protection provided by non-MDC owned watershed land, actual enforcement will be a constant challenge due to the shear magnitude of the potential problem. For instance, the MDC property line around the Quabbin alone is approximately 150 miles long. New acquisitions may increase this figure, although some purchases will actually simplify and shorten the boundary. In all cases, the protection provided by boundaries is enhanced by regular maintenance to keep them visible, and by immediate identification and resolution of encroachments.

a. Maintenance

Maintenance of MDC boundaries is a fairly straightforward, if daunting task. At the time of original acquisition, property lines are legally surveyed and blazed, and boundary markers (generally iron pipes or cement posts) are set at corners. On a regular 10 year cycle, these boundaries are kept visible by the forestry staff, primarily by clearing brush along the line and repainting blazes. This regular perambulation of the boundaries also serves to identify encroachments, discussed in greater detail below.

In addition to regular boundary maintenance, Division staff maintains approximately 50 miles of 40 foot wide fire line around the land within the Quabbin Watershed System. This line is kept clear through regular cutting (currently a three-year rotation), and serves primarily to prevent fires that start on private land from moving onto MDC properties. It also reduces MDC liability for fires that spread from its own land toward private land, by "breaking" these fires at the property line.

b. Encroachments

The following is a list of the categories of encroachments that have been reported just inside of Division boundaries:

- Water and Soil Impairment
  - -dumping of debris and hazardous materials
  - -storage of hazardous materials
  - -grazing of animals and manure storage

- Forest and Land Destruction
  - -cutting, removal, and damage of trees and plants
  - -disturbance or removal of soil and ground cover
  - -paving or covering of soil and ground cover
  - -grading or filling land
  - -removal of gravel or loam

- Construction
  - -installation of fences
  - -construction of sheds, cabins, walls, signs, docks, and buildings

- Boundary Destruction
  - -removal or destruction of stone and concrete bounds, iron pipes, and line trees

Once an encroachment is discovered a series of letters and field inspections are required in order to ensure compliance with the actions recommended by the Division. A small number of encroachments need to be resolved through court actions that require a great deal of additional police and Division staff time. Where possible, the Division strives to resolve encroachments outside of the court.

From 1988-92, five boundary encroachments were discovered and completely resolved on the Quabbin watershed. These included one dumping incident, three incidents of illegal cutting of vegetation, and one building encroachment. Most of these encroachments were resolved in the period of 1988-9 when a civil engineer at Wachusett was assigned to investigate and resolve encroachments on a part time basis. Most encroachments are discovered by field staff (civil engineers and foresters) while performing routine boundary marking or survey of areas where boundary lines are unclear. At this time, many of the most obvious encroachments have been identified and resolved. Encroachments are often discovered as new lands are acquired, and there are local areas within the Quabbin watershed where exact boundaries are unclear and encroachments are likely. It is felt that the best method of preventing new encroachments is by swift and effective resolution.

In order to reduce the number of encroachments, it is recommended that all new land purchases be surveyed just prior to purchase unless recently recorded survey plans for the land exist. Currently, only parcels that are to be subdivided and those with poor deed descriptions or unclear boundaries are surveyed prior to purchase. However, at an average cost of $10,000 per survey, the Division needs to dedicate increased resources to survey as part of its land acquisition program. The

addition of MDC survey crews for land acquisition would have the double benefit of reducing contract costs associated with land acquisition as well as reducing boundary encroachments on newly acquired lands.

4. Policing

This plan focuses on the management and protection of MDC watershed lands. Policing of public access and recreational activities is contained in public access plans done for Quabbin and Ware River. Policing is necessary in the following categories in order to support this plan:

- patrol and enforcement of violations of public access regulations that may degrade water, forest, wildlife, and cultural resources;

- patrol and enforcement of illegal activities such as dumping and boundary encroachment that may degrade water, forest, and wildlife resources;

- patrol and spot checks of all permit access to assure that permittees are in compliance with permits.

In order to assure that adequate policing of the above activities occurs, Division staff meet regularly with the Massachusetts State Police at Quabbin to assure that adequate police attention is given to patrols of property boundary and interior areas. Patrols focus on priority areas where violations are most likely (for example, at boundary areas near highly populated areas, at areas of concentration of cultural resources where violations have occurred, at areas where dumping or illegal vehicle use has occurred, and at areas with high recreational use).

5. Fire Protection

The MDC is committed to protecting the watershed forest, as well as watershed visitors, from the impacts of forest fires. While light burns in forest areas without forest regeneration cause little harm, hotter fires, especially in areas with younger forests, can cause serious impacts including death of both understory and overstory trees and exposure of mineral soil over large areas, causing an increased potential for overland flow, erosion, and nutrient loading. Two fires in the 1950's at Quabbin (one north of Route 122 and one on the Prescott Peninsula) were of this nature, killing understory and overstory vegetation. All fires can endanger the visiting public and adjacent landowners.

Nearly all recent wildfires at Quabbin have been caused by the visiting public. Over the past ten years, there have been 12 wildfires covering approximately 60 acres. Nearly all these fires were associated with illegal campfires or improper disposal of smoking materials. In the 1986 Forest and Wildlife Management Plan, the Division recommended that the following steps be implemented in order to minimize the danger of wildfires caused by the visiting public:

- Strictly enforce the prohibition against landing of boats on islands and the shoreline of the reservoir, and

- Eliminate all public access to the Reservation during times of extreme fire danger conditions.

Through increased education and enforcement efforts, MDC has reduced the number of illegal boat landings. MDC did close the watershed to public access during a brief period in October, 1984 due to extreme fire danger conditions. In a joint MDC/DEM meeting in March, 1994, it was agreed that during periods of extreme fire danger, the two agencies would cooperate to provide trained personnel to keep fire watch from the tower at Mt. Grace in Warwick State Park. This site provides an excellent view of Quabbin and is best situated for triangulation with the Pelham and Princeton towers.

The 1986 Quabbin Forest and Wildlife Management Plan also recommended the following actions to improve the Division's ability to quickly suppress wildfires:

- Improve cooperation with local fire departments,
- Improve forest road conditions in areas of poor access and high fire hazard and risk,
- Improve training of Division staff in fire suppression,
- Implement a fire watch during extreme fire situations.

Since 1986, the Division has made measurable improvements in many of the above areas. A fire policy was drafted in 1987 and has been improved and updated as recently as June, 1994. This policy specifically outlines the steps necessary for suppression of wildfires on MDC lands. (Complete contents of the most current fire policy is included in Supporting Appendices: Forest Fire Policy).

Through constant communication with town fire departments and the Department of Environmental Management fire control personnel, the Division has improved the coordination of fire suppression. Effective coordination with local fire departments is critical as the local Fire Chief is the person legally in charge of a fire fighting operation. MDC's role is to assist the local fire department and to assume responsibility only at the direction of the local fire chief (usually for "mop up" operations). The addition of a radio system at Quabbin that is linked to the DEM fire control personnel has greatly improved communications during wildfires.

Since 1986, many Division employees have completed the U.S. Department of Interior, National Park Service, Wildfire Control Training. 23 current employees have active certification through this training. In addition, employees receive training at controlled burns conducted annually at Quabbin. In order to participate on a fire crew, an employee must have National Park Service certification (which must be renewed every five years) and have participated in either a wildfire or controlled burn or attended an approved training program within the last two years. MDC has assigned one staff member to be the Fire Coordinator and this staff person receives yearly intensive fire control training.

Extensive progress has been made in the repair and maintenance of the forest road system at Quabbin in the past five years, which has improved access to most areas of the watershed (see next section for detailed report on roads). The Division has also acquired fire fighting apparatus that improves its readiness in fighting fires.

The current Division fire policy requires that the Quabbin Hill tower be staffed for fire surveillance when DEM staffs adjacent fire towers during hazardous fire conditions. The closure of the watershed to all visitors is deemed an extreme measure and would only be called for in time of drought or when the Division of Fire Control of the Department of Environmental Management has rated the fire danger for this zone as extreme for a period of not less than five consecutive days. It is recommended that the MDC Commission approve this aspect of the fire policy so that delays are not encountered in implementing watershed closings.

Over the past five years, the Division has upgraded much of its fire equipment including new fire hose, two floating pumps, and a 250 gallon tank and pump fit to the MDC log skidder, which can access the most remote areas. However, the Division's main fire fighting vehicles are two 2-wheel drive fire trucks with 500 gallon tanks, dating to 1965 and 1964. The Division is investigating the purchase of two four wheel drive vehicles with 250 gallon slip-on tanks. These vehicles would be fire equipped only during spring and fall fire seasons, freeing them up for other uses at other times of year. These smaller vehicles can more easily gain access to remote areas where most fires occur. Two additional 100 gallon slip-on tanks would be purchased to mount on existing work vehicles and be used as patrol vehicles when the Reservation is closed during extreme fire danger and would be available in the field whenever the fire danger is high.

6. Access Roads

a. Maintenance

The Quabbin internal road system is essential in order to gain access for key watershed management activities including fire protection, forest management, water sampling, research, and police patrols. The proper maintenance of access roads can greatly reduce the deposition of sediment and organic matter into nearby tributaries.

The MDC Quabbin watershed lands have a road system in excess of 200 miles that provides vehicle access throughout most of the watershed area. These roads date to the pre-reservoir communities in this area. Many were well-constructed, well-drained roads and have been partially maintained by MDC. There are also numerous farm lanes, logging roads, and seasonal access roads that provide emergency and limited seasonal access to large tracts of forested watershed. Of the 58,000 acres of MDC Quabbin lands, approximately 687 acres (1.2%) are in access roads.

The condition of Quabbin's gravel roads has been steadily improving over the past decade. During the 1980's, Division foresters included the cost of upgrading access to forest management sites in the timber sale contract, although this practice has since been discontinued. The addition of the watershed maintenance personnel in 1987 has greatly added to the miles of existing roads that have been improved. The next decade will focus on the fine tuning of the access system, gradually moving from a reconstruction to a maintenance orientation.

The amount of maintenance needed on each type of roadway is difficult to predict precisely. The work needed to keep all major roads open throughout the year is largely dependent on the weather. Major storm events affect roadways as trees or limbs fall into the roadway, making them impassable. Crews are dispatched after each major storm event to clear roads of fallen debris. Washouts due to culvert failure or clogged drainage ditches occasionally occur after major storms.

The Division has identified approximately 42 miles of road that will need grading and the addition of processed gravel this decade, and approximately 48 miles that are in need of higher intensity treatment, including the addition of bank run gravel as well as grading and topcoats of processed gravel. This road work will utilize approximately 60-80,000 yards of gravel, including both bank run and processed gravel. Gravel will come from eight pits, listed and characterized below:

Pit #1 - Gate 5 - active, with current stockpiles of processed gravel.

Pit #2 - Whitney pit, between Gates 16 and 17 - active, both bank-run and processed, requests received from Town of New Salem to share use of this pit, as per existing legislation.

Pit #3 - Gate 17 - proposed pit at North end of first field inside Gate 17. Requested by University of Massachusetts, to maintain road to radio observatory site. Has been inspected and approved by all necessary MDC staff.

Pit #4 - Atkinson Hollow (Gate 17). Not currently used. Material is large cobbles, requiring. processing. Site may become important for work on Prescott Peninsula roads.

Pit #5 - Griswold/Wendemuth homestead, south of observatory along Prescott Ridge. Currently active; partially reclaimed (loamed and seeded).

Pit #6 - Gate 29. Bottom of Gate 29 road. Area nearest reservoir was recently reclaimed. Active site from this edge inward.

Pit #7 - Gate 41. Active pit, currently shared with Town of Petersham, as per existing legislation.

Pit #8 - Gate 43. "Mixer Pit". Currently active, with stockpiled processed gravel.

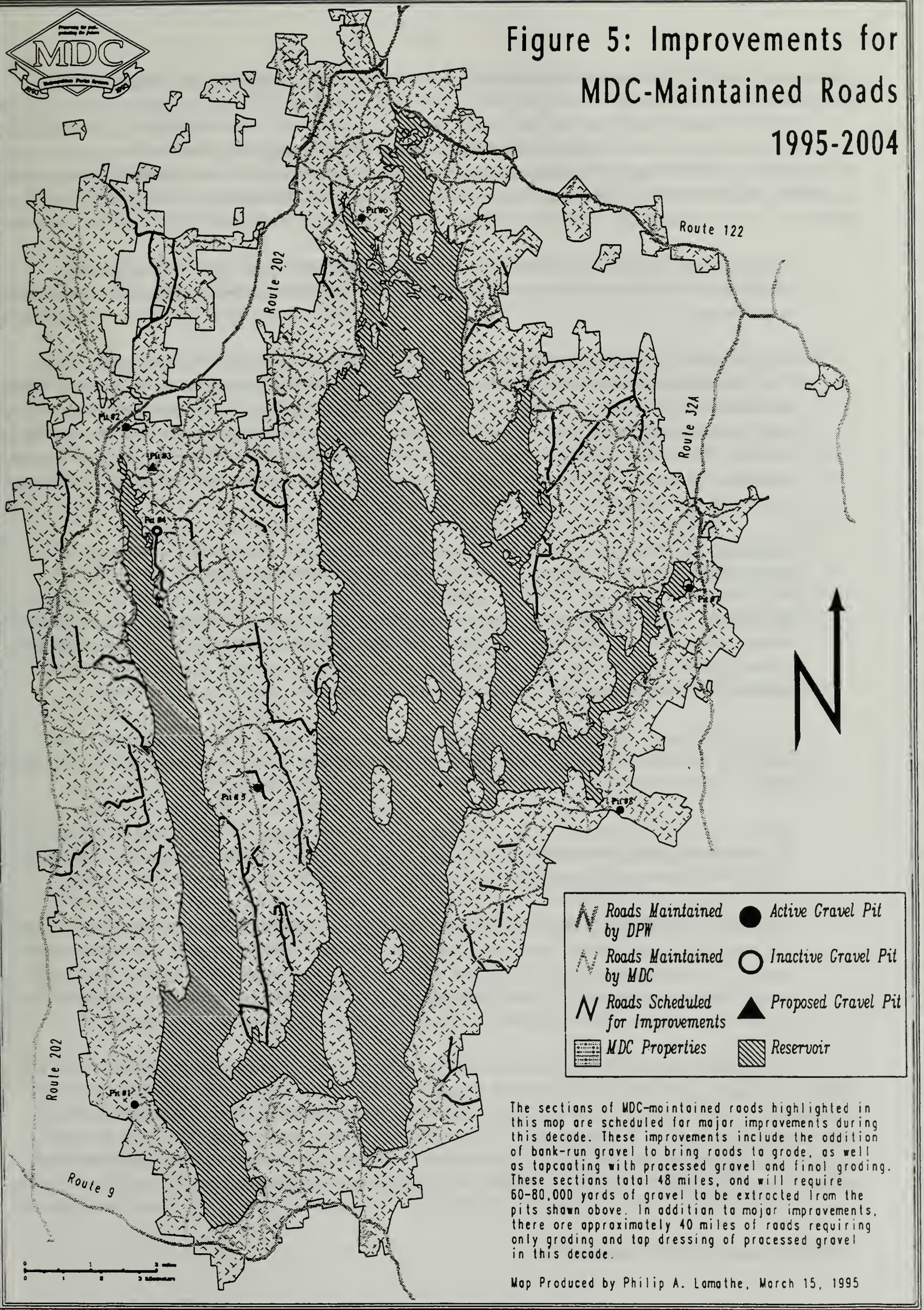
Potential water quality impacts from the active use of these gravel pits are strictly controlled. As gravel deposits are exhausted, the land is reclaimed by the MDC to tree cover as soon as possible. Staff responsible for the use and control of these pits are trained in water quality protection as well as gravel pit reclamation techniques.

The sections of Division-maintained roads that are scheduled for major improvements, as well as gravel pit locations are shown in Figure 5.

b. Best Management Practices for Road Maintenance Activities

The objectives of forest road maintenance on the watershed are to provide for vehicle access to support key watershed management activities, and to minimize adverse water quality impacts associated with this road system. Activities that are dependent upon a good access road system include fire protection, forest management, water sampling, research, and police patrols. These activities require stable, properly shaped and ditched road surfaces with adequate structures to manage

Figure 5: Improvements for MDC-Maintained Roads 1995-2004



The sections of MDC-maintained roads highlighted in this map are scheduled for major improvements during this decade. These improvements include the addition of bank-run gravel to bring roads to grade, as well as topcoating with processed gravel and final grading. These sections total 48 miles, and will require 60-80,000 yards of gravel to be extracted from the pits shown above. In addition to major improvements, there are approximately 40 miles of roads requiring only grading and top dressing of processed gravel in this decade.

Map Produced by Philip A. Lamothe, March 15, 1995

storm event runoff. The vast majority of road maintenance on MDC properties is accomplished by Division staff and equipment.

To accomplish these objectives Division crews use various mitigating procedures to protect stream water quality during routine maintenance activities. These procedures are outlined below. It should be noted that specific sites may require special systems not described here, such as the use of geotextile, erosion control blankets, subsurface drainage, and rip-rap materials.

Shaping Road Surface: The basic component of a stable road is the proper crowning and ditching of the road to allow storm runoff to flow off the travel surface and be collected in the roadside ditch.

Relief Ditches, Relief Culverts, and Waterbars: The frequent removal of storm water runoff from the roadside ditch is important to limit the amount of soil and gravel that is washed from an area during an event. The spacing of the relief structures is determined by combining site data such as; slope of the road, slope of adjacent woodland, soil type and depth, and physical structure of the road. The general rule of thumb is to place relief structures as often as the landscape allows on most slopes. Relief structures, wherever possible, will discharge the storm runoff not less than 50 feet from streams or wetlands.

Detention and Retention basins will be installed where needed during road reconstruction activities to reduce the velocity of stormwater and increase infiltration.

Dry Season Work: Except for emergency repair work, some major bridge work (which may extend beyond dry periods), and emergency culvert replacement, road work will generally be accomplished during dry periods (primarily summer), when low water flow and stable soil conditions will help mitigate impacts from soil disruption.

Use of Silt Fence / Hay Bales: Whenever road maintenance work requires disturbance near wetlands, the wetland will be protected by properly installed hay bales or industry standard silt fence.

Seeding of Disturbed Areas: Upon completion of road maintenance projects areas of disturbed soil will be graded and seeded with quick growing grass species. The Division has purchased a "hydro-seeder" for this purpose.

Special Road Surfaces: Because of the huge variation of historical forest road construction and use, alternative road surface materials may be appropriate in limiting loss of material through erosion. Forest roads that are rarely used may be shaped and seeded with grass. These roads would then be maintained by yearly mowing and culvert cleaning. Depending on location and use, these roads may also be blocked by use of barways to keep out all but essential traffic.

Two additional road surface materials will be examined in this management period: 1) paving (which is currently prohibited by legislation) to stabilize steep road sections and 2) calcium chloride applications to control dust (a form of erosion) and consolidate fine surface materials in high traffic areas, such as the roads to Fishing Areas. The benefits of utilizing these materials will be carefully weighed against any potential threats to water quality, and there are no plans for wide application of either without thorough investigation of their effects and proper authorization.

It is the Division's intention to limit washouts by replacing under-sized culverts with structures that will meet standards for a 50-year flood. Both culverts and ditches will be kept open and clear of all restrictions in order to prevent the back up of storm runoff and the resulting washout. Beaver control structures in use on the watershed will be designed to accommodate the full specified flow of water through the culvert. In addition, the Division will continue installation of overflow spill areas (reinforced, low areas on a road adjacent to major streams) capable of spilling the flow from a 100 year flood on major tributaries.

Other general road maintenance occurring on a regular basis includes grading, removal of hazardous roadside trees, roadside mowing (which facilitates drainage and keeps roads open), and the processing and spreading of gravel as needed.

As part of its land acquisition program, MDC acquires access roads or the land abutting these roads. It is the Division's policy to install gates to limit access to all newly acquired roads in order to minimize erosion and illegal dumping along these roads. For specific road areas where gates are proposed, and for a more specific and complete description of the road maintenance plan (including standard operating procedures for road work and road standards for different uses) refer to Supporting Appendices: Roads and Gates.

c. Internal Review of Proposed Roadwork or Gravel Operations

Much of the roadwork conducted on the watershed is routine and of a maintenance nature. Occasionally however, new access roads must be constructed, or new sources of gravel developed. In these cases, since the operations may result in habitat changes and possible impacts on water quality, wildlife, or cultural resources, the following procedure will be followed:

1) Development of a plan showing the location to be affected, time sequence of removals and procedures to be employed,

2) Consultation with Division Section Superintendents, Environmental Quality and Wildlife staff, and the MDC Chief Archaeologist to determine that no significant impacts will occur to water quality, wildlife, or cultural resources,

3) Consultation with and completion of all necessary approvals from the Department of Environmental Protection, Department of Fisheries, Wildlife and Environmental Law Enforcement (for information on both fisheries and rare species impacts), the local town Conservation Commission or other local bodies, and any other governmental entity with jurisdiction over the chosen site.

4) Final approval from Director of Natural Resources.

7. Areas with Special Management Restrictions

The 1972 Quabbin Reservoir Watershed Management Plan delineated areas on which conventional forest management practices were either impractical or otherwise undesirable. That plan included 3,360 acres in "Aesthetic Areas" and 3,200 acres of "Protection Areas", which included

islands, rock quarries, caves, rock outcrops, hill top views, cellar holes, mill sites, exceptional forests or individual trees, and areas that have been undisturbed for the past 100-150 years. The "Protection Areas" also included 1,350 acres in the Cadwell Creek watershed, a control area for a watershed study done by the University of Massachusetts. While the Division had not planned cutting in the "Protection Areas", commercial forest management in the "Aesthetic Areas" was allowed if special logging techniques were used. The plan also included 1,440 acres in "Wildlife Wetland Areas" (chiefly beaver flowages), where no cutting was planned.

In the 1986 Quabbin Forest and Wildlife Management Plan, 7,600 acres were designated in the "Protection Zone". This zone included steep, rocky, or extremely wet sites; exceptional, rare, or endangered plant communities, or wildlife habitat; and significant cultural resource sites. No forest management was permitted in this zone.

The purpose of this section is to update the concept of areas where special management restrictions apply. As the Division continues to refine its analysis of the watershed protection provided by the lands under its control, some refinements in the restrictions have been made. For instance, efforts to maintain an understory (for the reasons cited throughout the plan) seems more crucial in riparian zones than in areas that are distant from tributaries or the shoreline. While riparian areas have traditionally been untreated, understory maintenance will be a priority for this decade, and will include such practices as planting and non-harvest silviculture to stimulate understory growth.

Within this management period (1995-2004), no specific changes have been proposed for management of past "protection zones" with the exception of limited (approximately 200 acres) application of non-harvest silviculture. Table 9 lists the areas with special management restrictions as they stand currently. The cumulative sub-basin approach to setting priorities will aid in directing management proposals for these areas, and the Division is planning to form a special advisory committee with technical expertise to weigh the benefits and costs of these and other management proposals (see Section VII.C.)

Included in the lands in Table 9 are two major categories:

- areas with uncommon, rare, or potentially rare resources,
- areas where commercial forest management may cause unacceptable impacts.

The first category includes areas such as uncommon forests, communities containing rare, endangered, or threatened plant or animal species, and historic/prehistoric sites. Examples of these areas include sheltered stream valleys that have not been impacted by human or natural disturbances for extended time periods, diverse or unique regions designated as Natural Areas, and cellar holes and Native American encampments and work sites. The delineation of each area may also designate an appropriate buffer zone around the resource.

The second category includes commonly occurring but fragile areas such as bogs, forested wetlands, marshes, wet meadows, vernal pools, areas with fragile wetland soils, and slopes greater than 30%.

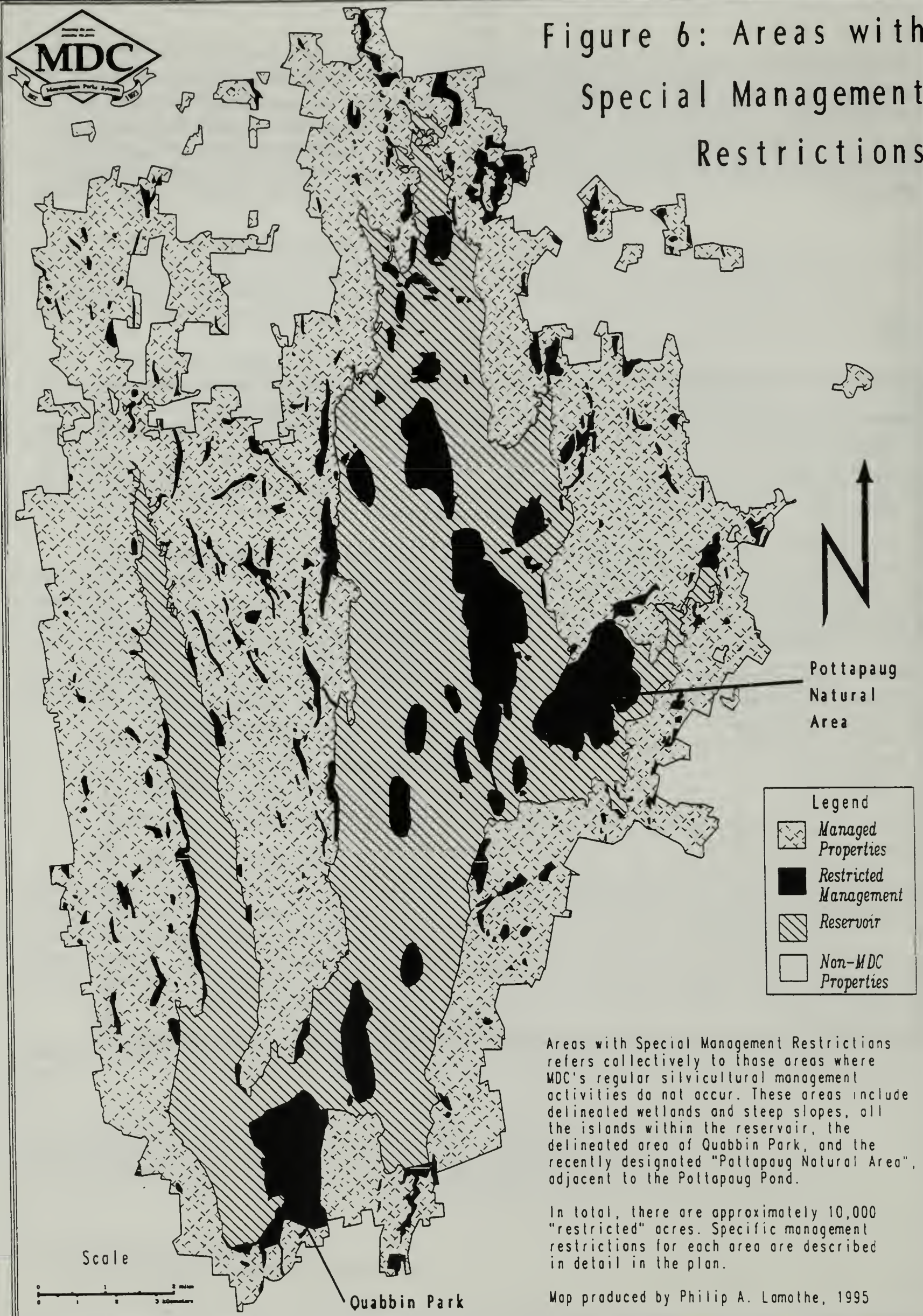
Approximately 10,000 acres of MDC Quabbin lands have been classified as "Areas with Special Management Restrictions". These areas include large blocks of land such as the 3,712 acres of reservoir islands and two blocks in excess of 1,000 acres each in Quabbin Park and adjacent to

Pottapaug Pond. All identified wetlands and steep slopes are included, some of which are contiguous areas of several hundred acres (e.g. the steep Pelham shoreline, or the wetlands along the East Branch of Fever Brook). In addition, many small areas have been included, representing sensitive resources and buffers around historic and rare wildlife habitat areas. For example, Division and University of Massachusetts staff have mapped, from aerial photos, more than 500 vernal pools across the Quabbin watershed.

Table 9: Areas with Special Management Restrictions

AREA	RESTRICTIONS
Islands 3,716 acres	No management
Steep slopes 1,712 acres	No management
Wetlands 2,272 acres	No management except limited beaver control - see beaver policy
Rare and endangered species habitats	Subject to restrictions upon advice of Division of Fisheries and Wildlife
Riparian zones adjacent to tributaries and the Reservoir edge	Subject to restrictions of FCPA (Chapter 132); limited (200 acres) non-harvest silviculture
Quabbin Park 1,058 acres	Limited management including deer fencing, tree planting, non-commercial regeneration cuts, and roadside salvage cutting
Pottapaug Natural Area 1,183 acres	Restricted by recent designation by MDC as Natural Area, in 1991
Disturbance-sheltered areas	Not restricted in past, these areas will receive relatively low intensity management to begin establishment of regeneration
Areas of Historic, Cultural, or Natural Significance	Varies from no management to selective restoration and maintenance

Figure 6: Areas with Special Management Restrictions



Areas with Special Management Restrictions refers collectively to those areas where MDC's regular silvicultural management activities do not occur. These areas include delineated wetlands and steep slopes, all the islands within the reservoir, the delineated area of Quabbin Park, and the recently designated "Pottapaug Natural Area", adjacent to the Pottapaug Pond.

In total, there are approximately 10,000 "restricted" acres. Specific management restrictions for each area are described in detail in the plan.

Map produced by Philip A. Lamothe, 1995

Areas that have been set aside for the reasons mentioned above also can function, on a long or short-term basis, as areas from which background measurements can be taken for comparison to areas that are directly under management. The Division will retain this function, and will regularly reevaluate the sufficiency of current "restricted" areas for establishing background information.

GIS analysis has provided some preliminary information on this topic. For instance, of the 12 common forest types occurring on the Quabbin Continuous Forest Inventory plots, six are also represented on CFI plots that fall within the "restricted" areas (most of the "missing" types are generally uncommon, such as red spruce, larch, or pitch pine. Each of the five MDC soil types (see Section II.B.1.) is well-represented within the "restricted" areas. There are 189 acres of plantations and 150 acres of open spaces within the "restricted" area. All wetlands and steep slopes are part of the "restricted" areas. Approximately 61% of the "restricted" area is "exposed" to hurricanes (according to Harvard Forest model), 22% is "intermediate", and 17% is "sheltered". These percentages are similar to those for all MDC properties on the watershed (67%, 24%, 9%). If a particular soil/vegetation complex or other land type is of interest and is not represented within the restricted areas, MDC will seek ways to fulfill this need. This issue will be further evaluated by the Science and Technical Advisory Committee (see Section VII.C.)

Within the "Areas with Special Management Restrictions" is a block of 1,183 acres bordering the reservoir and Pottapaug Pond (Figure 6). This area was recently added to this category to address the public interest in a block of accessible forest that was allowed to grow and change without silvicultural intervention. The area was chosen because it offered a wide variety of forest types and wildlife habitats, but was hydrologically removed from the Wachusett Aqueduct and sheltered from typical, south-easterly hurricane winds. The details of long-term management of this area, including fire, salvage, recreation, road maintenance, and plantation silviculture policies, are still being discussed (for instance, the decision to let a wildfire burn rests in the hands of the fire chief of the town, not with the MDC). The final definition of policy for this area will be determined by the Science and Technical Advisory Committee (see Section VII.C.).

B. Forest Management

1. Forest Management Alternatives

Based on the extensive literature review of watershed management issues presented in the SUPPORTING APPENDICES to this plan, the watershed management principles presented in the preceding section, statutory requirements, and public input during earlier phases of the development of this plan, three alternative approaches for the management of Quabbin lands were developed. The purpose of this section is to describe and evaluate these three alternatives and to select one for implementation.

All three alternatives are based on the premise that a diverse and vigorous forest comprises the optimal watershed cover condition. Although forests are only one of many elements that affect water quality in tributaries and reservoirs (other elements include soils, weather, surficial and bedrock geology, topography, wetlands, and air pollution), forests can be purposefully managed. Therefore, choosing an optimal approach to forest management is a critical part of a watershed management plan. In this sense, an alternative that would minimize human intervention is still a purposeful "management" choice.

In evaluating the three forest management alternatives, the Division drew heavily on the work of F.H. Bormann and G.E. Likens (1979b), Pattern and Process in a Forested Ecosystem. That work, based on nearly two decades of study of natural and human influences on the Hubbard Brook experimental watershed in New Hampshire, provides a comprehensive current model of the structure, function, and development of one forest ecosystem (northern hardwoods) in New England. The Hubbard Brook model, and the analysis of associated hydrology and biogeochemistry, were used throughout the comparison of watershed forest management alternatives for the Quabbin watershed, in part because there is not yet a more localized, equally comprehensive model.

The Hubbard Brook model is based upon biomass accumulation following an artificially imposed disturbance - clearcutting with no removal of felled trees from the site. According to Bormann and Likens (1979b), most forests proceed through the following general stages after a disturbance: **REORGANIZATION** (where nutrient and water losses occur until regrowth is firmly established), **AGGRADATION** (where the system efficiently accumulates biomass with minimal nutrient export and reduced water yields), **TRANSITION** (where the even-aged forest "breaks up", with associated losses of biomass, accumulated nutrients, and water) and the **STEADY-STATE** (where inputs equal outputs, overstory openings balance maturing forest, and total biomass fluctuates about a mean).

Although it was developed from extensive study of the northern hardwood forest in New Hampshire, and the bulk of the empirical evidence relates to the Reorganization and Aggradation stages, the authors believe their model has wide application to other forest ecosystems (Bormann and Likens 1979b:175-178). The authors acknowledge differences in the disturbance regimes of northern vs. central New England (e.g. a hurricane frequency of 1:250 years in northern New England vs. 1:100-150 years in central New England) (Bormann and Likens 1979b:200). Among other effects, these differences may well have influenced the evolution of disturbance-resilience within the respective forest ecosystems. Nonetheless, the basic ecological principles described for the northern hardwood forest should serve as a useful tool for comparing the effects of various alternative management strategies on the Quabbin forest ecosystem.

The three alternative management approaches chosen for consideration represent three feasible, yet very different ways to manage the forest on the Quabbin watershed. The alternatives are:

> **ALTERNATIVE #1: "ACTIVE MANAGEMENT FOR WATER YIELD ENHANCEMENT"** - active management with the objective of moderately increasing water yields while minimizing impacts upon water quality and maintaining forests over most of MDC lands, utilizing commercial timber harvesting to maintain even-aged forest conditions and create forest openings. This alternative attempts to address the statutory requirement (Ch. 372 (1984), § 116) to consider water yield enhancement in the development of management plans.
>
> **ALTERNATIVE #2: "ACTIVE MANAGEMENT FOR WATER QUALITY PROTECTION"** - active management with the goal of long-term water quality protection, accomplished by increasing the long-term stability of forest cover to mitigate future impacts from natural disturbances and air pollution, utilizing primarily uneven-aged silvicultural methods, accomplished through commercial timber harvesting to deliberately increase diversity of tree sizes and species. This alternative attempts to address the statutory requirement to "assure the availability of pure water for future generations" (Ch. 372 (1984) § 105).

ALTERNATIVE #3: "NATURAL MANAGEMENT FOR WATER QUALITY PROTECTION"- limited management with the goal of long-term water quality protection, accomplished by the establishment of an equilibrium forest that persists for long periods of time and responds to natural disturbance, utilizing minimal silviculture. This alternative attempts to address statutory requirements for future water quality protection while also allowing natural growth and change in the forest, including creation of unmanaged natural areas and, eventually, old-growth habitat, and eliminating commercial forest management and active wildlife management.

In the following sections, each alternative will be described and compared using evidence in the scientific literature regarding:

a. Description and underlying principles;
b. Description of how the watershed would look;
c. Impacts upon long-term water quality;
d. Impacts upon water quantity;
e. Response to potential air pollution impacts;
f. Difficulties involved in implementation;
g. Impacts on non-water resources.

Alternative #1: Active Management for Water Yield Enhancement

a. Description and Underlying Principles

Studies at watersheds in New Hampshire, Pennsylvania, West Virginia, North Carolina, and Quabbin Reservoir show that water yields can be increased through forest cutting, with yields generally increasing with the percentage of forest removed. Most yield increases occur as baseflow during the growing season (Hornbeck et al, 1993). The basic principle is that large amounts of the water in a basin may be lost to evaporation and transpiration from forested cover. Depending upon the size and location of the opening, the rate of regeneration, and the forest type, slope, aspect, soils and weather of the site, cutting can cause yield increases that last up to ten years. Cuttings that thin the forest or create very small openings (as in uneven-aged or irregular shelterwood systems) are much less efficient in increasing water yields, with the removal of approximately 25% of a basin's mature forest cover necessary to initiate measurable responses (Hornbeck, 1993; Mrazik et al, 1980).

Assuming forest cover was retained for protecting water quality (so that no permanent field openings were created), this alternative would involve regenerating the Quabbin forest in blocks of ten acres or more to create a patch-work of even-aged stands of forest across the watershed. A moderate approach could involve management of pine types on a 60 year rotation and management of hardwood types on a 80 year rotation. One third of the forest would be removed every 25 years (650 acres per year) in openings varying in size from 10-25 acres. In order to minimize impacts of future hurricanes, cuttings would be prioritized by predicted susceptibility of sites to hurricane disturbances (see Alternative #2 for more discussion on hurricanes), as well as by susceptibility to other natural disturbances. In addition, light "preparatory" cuts would be conducted on 1,000 acres per year, with the intent of establishing advance regeneration (currently lacking in most areas due to past deer browsing). Initial implementation would be complete in 50 years at which time forests in the 0-25, 25-50 and 140+ year old forest layers would be present.

b. Description of How The Watershed Would Look

The watershed is currently an even-aged forest and this alternative would maintain even-aged cover. However, the current two large blocks of 55 and 90^{+} year old forests would be diversified into many smaller blocks of varying age. Under this alternative, approximately one third of the forest would average 0-25 years and one third 25-50 years, with the remaining third in a 50+ year old forest. The most noticeable difference would be the increased area of cleared and young forest and the increased diversity of forest layers within any given area of Quabbin.

Blocks of regeneration could be designed so that they were less discernable on the ground or from vistas, by use of irregular shapes and borders. With larger openings used to foster regeneration, a broader range of light and moisture regimes would occur. As a result, a larger diversity of plant species could be seen within a given area, the most of the three alternatives. Wildlife diversity, especially birds, would likely be greatest in this option, and wildlife would be most easily observed in this forest by the visiting public. Dense regeneration would be evident in openings and a developing understory would be evident on the 1,000 acres per year where light "preparatory" cuts had been recently completed. A major hurricane would blow large numbers of trees down, with damage focused on large blocks of maturing trees on exposed sites.

c. Impacts Upon Long-term Water Quality

The impacts of even-aged management vary with intensity and location of regeneration cuts, intensity, layout and maintenance of road systems, planning and supervision of logging and access roads operations, and the type of even-aged silviculture applied (for example irregular shelterwood systems versus large clear cuts). Given that a small percentage of the watershed would be affected each year and site location and supervision would be carefully implemented, impacts upon the three parameters most likely affected - turbidity, nutrient levels, and stream temperature - could be minimized. One of the keys to reduced turbidity impact would be the use of MDC's existing access road system and the addition of a minimum of carefully located forwarder and skid roads. This option is the most efficient in accessing the site with regard to roads (regeneration cuts occur infrequently and are concentrated). Other "best management practices" that would reduce turbidity and stream temperature impacts for this alternative include leaving forested filter strips adjacent to streams, using proper culvert placement and installation, avoiding large open areas on any given sub-basin to avoid large peak flows, and exercising stringent control over layout of forwarder and skid roads (see Dyrness, 1965; Swank, 1972; Stone, et al, 1979; Patric, 1978; and Verry, 1986).

The amount and type of cover removed, as well as soil texture, location in the watershed, litter condition, and the steepness of the land, affect the potential for nutrient increases after cuttings. Strip cutting of one third of a watershed in New Hampshire caused nitrates to double, while clearing of 8% of Quabbin's Dickey Brook drainage caused only slight solute fluxes attributed to the increased water yields that were limited to the first year after cutting (Shanley, 1993 pers comm). Thin, coarse, nutrient-poor soils are perhaps the most susceptible to nutrient loss after cutting although nitrogen losses may occur more quickly on fertile soils (Vitousek et al, 1979). Martin and Pierce (1980) reported maximum nitrate losses in the first year when the lower section of a watershed was clearcut and maximum losses in the second year when the upper section of a similar watershed was clearcut. Overall, more nitrate leached when the drier, less fertile upper section of the watershed was cut.

Van Miegroet and Johnson (1993) reported that nitrate leaching on high nitrogen-content soils was more sensitive to atmospheric inputs, forest age, and tree nitrogen uptake rates.

As the total load of nutrients and sediment increases with the volume of water flowing in streams, additional water yields carry additional nutrients and sediment to the reservoir. While extensive cutting could generate large peak flow water yield increases, MDC would not accept any program that reduced water quality. Verry (1986) reported that, in general, cutting affecting less than 20% of a watershed will not produce detectible increases. Therefore, spreading cutting around the watershed would regulate yields. Moderate levels of cutting increase yields chiefly during low-flow periods. However, it is unlikely that any increased sedimentation from channel scouring would result from this increased flow.

Bormann and Likens (1979b) analyzed various stages of forest development with regard to nutrient loss in northern hardwood forests and describe the first twenty years after clear-cutting as the "reorganization" phase where large losses of water and nutrients generally occur. Careful location and timing of block cutting and prompt site regeneration would be necessary in order to minimize losses of nutrients. While the concentrations of dissolved organic carbon and phosphorus, parameters of great concern to water suppliers, vary little with forest disturbance (Hobbie and Likens, 1973), the increases in flow resulting from extensive clearings can cause excessive tributary loading of these elements.

The water quality influence of natural disturbances that occur within the managed, even-aged forest will vary with intensity, location, and type of damage, with greatest impacts from large-scale disturbances such as hurricanes, especially when they strike areas of tall forest cover with minimal understory development, on steep, erodible soils. Management for an even-aged forest accomplishes the objective of maintaining a portion of the forest in younger trees, but these occur as separate, relatively large blocks rather than widely distributed smaller patches. Consequently, age- or size-specific disturbances may leave behind large blocks of temporarily uncompensated damage, on those areas of the watershed where young, "reserve" forest is not in place.

One potential advantage of even-aged systems is that they present aerodynamically smooth canopies to face strong winds, with the exception of the junctions between managed areas. There is some evidence that these canopies will escape damage that the aerodynamically rough canopy of classic uneven-aged management might sustain (Matthews, 1989). However, the same text suggests that the only way to decrease total damage from catastrophic wind is to "increase the diversity of the stands in age and height, so reducing the proportion of the forest area that is at risk" (Matthews, 1989, p.31).

d. Impacts Upon Water Quantity

The 1985 "Task 7" study of increasing water yields at Quabbin through forest management predicted that an increase in water yields of 5 million gallons per day could be achieved through establishing 3,000 acres of grass cover, 1,000 acres of savannah cover, and converting 28,000 acres of dense forest to "low density" forest (50-70% stocking). Alternative #1 would focus on regenerating methods rather than thinnings, which are less efficient in creating water yields. Meaningful water yields could be achieved but actual estimates would require detailed modeling of average sites cleared each year with attention focused on north-facing slopes, conifer cover, and deep, unsaturated soils where higher yields will occur after cutting.

e. Response to Potential Air Pollution Impacts

Current literature regarding existing and potential impacts of air pollution on forests and water is reviewed in detail in the Supporting Appendices: Literature Review. The chief impacts of concern center around acid deposition, ozone pollution, metal deposition, and nitrogen saturation. Many researchers agree that predictions of future forest conditions should seriously consider air pollution impacts (Bormann and Likens, 1979a; Klein and Perkins, 1988). The interaction of pollution impacts with natural stresses and low nutrient sites, makes specific analysis and prediction difficult.

The potential problem of nitrogen saturation, defined as a declining ability of an ecosystem to retain added nitrogen, was first identified in 1981 (Aber, 1992). Researchers are concerned that acid deposition may also be adding significant amounts of nitrogen, originating chiefly from nitrogen oxides in air pollution. Because forest harvesting removes nitrogen and replaces older trees with more vigorously nitrogen-accumulating young growth, Alternative #1 may have ameliorating effects on the nitrogen balance in saturated systems, although the specific condition with regard to nitrogen saturation at Quabbin needs more research (see Supporting Appendices: Literature Review for a more complete discussion of this topic).

f. Difficulties Involved in Implementation

In general, this alternative presents the fewest difficulties to management implementation. Harvesting is concentrated and therefore easier to administer, as is the associated maintenance of active roads. Clearcutting, by definition, eliminates concerns about protecting the residual stand. However, because of the removal of the overstory and the thorough impact on any existing understory, unbuffered erosion of clearings with any slope would be a greater concern than in partially cut stands. Eliminating this concern would require extra care in the layout of harvesting areas, taking into account topography, the potential unbuffered travel distance of runoff (and therefore the width of the cut area relative to the slope), and proximity to water resources.

g. Impacts On Non-water Resources

This alternative would increase overall wildlife diversity, especially through establishment of areas of early successional growth. Mature forests would make up a large percentage of cover during the first 50 years. Revenues from the program would be increased over the current MDC program or Alternatives #2 and #3 because of the ease of harvesting. Areas recently cleared would look intensively managed while areas near the end of the rotation would look less managed. There are many possible variations of this even-aged approach, each designed to accommodate resource values in different ways. For example, reducing rotation length from 75 to 50 years on two thirds of managed areas and allowing the remaining one third to grow for an indefinite rotation length may meet the water yield objective while accommodating the values associated with older, unmanaged forest. Buffer areas around particular cultural, wetland, wildlife, or rare species resources could be designed to protect these resources, but some resources, such as vernal pools, would require special consideration if the surrounding forest were to be clearcut.

Alternative #2: Active Management for Water Quality Protection

a. Description and Underlying Principles

This alternative would focus on increasing the diversity of tree ages and species at each forest site through selective removal of individual and small groups of trees. The alternative would mimic and work with natural processes of endogenous disturbance (localized mortality and treefall), but would work to distribute disturbance in a deliberate manner across the watershed so as to limit both the damage and the nutrient export associated with large-scale exogenous disturbances. The alternative would intentionally balance three general structural components of the watershed protection forest:

1. The understory, which represents a "reserve forest" that is capable, through abundance and resilience, of surviving disturbance and quickly reforesting a disturbed site.

2. The midstory, which provides rapid, vigorous biomass accumulation and regulation of nutrient export.

3. The overstory, which gives depth to the forest filter, thus improving its ability to remove air and precipitation-borne pollutants, and regulates solar energy so as to maintain cool tributary water temperatures and slow the decomposition of soil organics, allowing development of a thick sponge-like mat, which further filters water and protects fragile mineral soils. The overstory is also the most prolific source of seed for the continuous rejuvenation of the forest.

To improve the ability of the forest to respond to species-specific disturbances (esp. insect/disease impacts), management would retain or enhance site-appropriate species diversity. Full implementation would be achieved in 60 years, when the three structural components listed above were in place on any given site. At that time, trees from 0 to 60 years old would be represented across the watershed, together with trees in excess of 110 years. Management intensity would vary by site susceptibility to major disturbances, maintaining a stronger understory/midstory component on sites where major disturbances are more likely to occur.

On average, silvicultural treatment would occur at any site once each 20-30 years, with approximately one third of an area regenerated at the time of treatment. Across the managed portions of the watershed, harvesting would create approximately 500 acres of openings (generally 1/10 to 1/4 acre) per year, a disturbance rate of approximately 1% of the total management area per year. This rate mimics natural endogenous disturbance rates, which average .5-2% in temperate forests (Runkle, 1985), but Alternative #2 would assure the deliberate, even distribution of these openings. Disturbance-sheltered sites would receive enough management to assure periodic establishment of regeneration. Across the watershed forest as a whole, approximately one-third of the overall area would, in the absence of major disturbances, contain trees that had reached ages greater than 110 years when full implementation is achieved in sixty years (see Figure 9). So long as these older trees remain vigorous, and especially where they have developed as sheltered small stands of exceptional trees, they may be retained indefinitely by future managers. Management overall would be geared to maintaining vertical diversity with a multi-layered forest occurring across most sites.

In most central New England forest sites, strong hurricanes, such as occurred in 1938, have exerted the greatest natural influence on long-term forest development, by restarting successional processes well before biological maximum ages of trees and stands are reached (Foster, 1988a). Other disturbances (tornados, widespread insect/disease, decline related to air pollution) are a concern for

watershed managers when they result in soil disruption from uprooting, create fire hazards from accumulated deadwood, or simply cause a loss of forest cover over large areas. Diversifying tree ages and species make-up in the forest will increase resilience and resistance to such impacts, especially on susceptible sites.

Alternative #2 follows the basic recommendation of Savill (1983) in applying silviculture to reduce windthrow risk by "improving the forest design" to that of a multi-layered forest in susceptible areas. By having forest regeneration developed across most watershed sites, the forest will be more resilient in facing wind and other future impacts such as air pollution, insects, and diseases (see Marks and Bormann, 1972 and Vitousek et al. 1979).

Several scientists have concluded that nitrate leaching, a symptom of nitrogen saturation, may be lessened with mid-successional forests due to increased plant uptake, reduced nitrogen in the forest litter, and increased microbial immobilization (Hemond and Eshleman, 1984; Murdoch and Stoddard, 1992; and Murdoch, 1993, pers comm). For example, Melillo et al. (1983) estimated the loss of nitrogen from a two year old pin cherry stand to be 43 kg/ha/yr, while that from a 50 year old beech-birch stand was estimated to be 4 kg/ha/yr.

By keeping openings small and spreading them throughout the forest, the impacts of regenerating the forest can be minimized. Parsons et al. (1994) studied nitrogen in soil solution at openings created by removing clusters of 1, 5, 15, and 30 trees in the Rocky Mountains and recommended selective harvesting (which creates an uneven-aged forest) if maintenance of undisturbed nitrogen soil conditions was desired. Interestingly, the uneven-aged selection system was also recommended by Cline (1939) as the preferred watershed management strategy, given the type of damage that occurred in New England forests from the hurricane the preceding year.

b. Description of How the Watershed Would Look

Since the current Quabbin forest is even-aged, with little understory development, the Alternative #2 forest would look quite different. In 60 years, this forest would have a mixture of sizes of trees within sight across the forest. Patches of dense small trees would be located next to 100-150 year old trees. On south and east facing slopes, dense, younger forest would be more prevalent, while on other areas older trees would be more dominant. Due to management, overstory trees would grow at an increased rate over the next 60 years when compared to Alternative #3. Ten or more tree species could be seen within a short walk in most areas. The forest would take on a layered appearance in most areas, with a visible understory, midstory and overstory present. Dead and downed trees would be evident. Recent evidence of logging could be found on some sites, but the average site would not have been logged within the past 10-15 years. A major hurricane would leave large numbers of trees down, but younger trees, which are less affected by wind, would survive and be immediately visible. Likewise, the replacement of large, contiguous blocks of older oak forest with a multi-layered, species-diverse forest would reduce susceptibility to species-specific pathogens.

c. Impacts Upon Long-Term Water Quality

This alternative is designed to maximize the water quality benefits of forest cover and minimize the negative impacts from forest management and natural disturbance - the two types of disturbances most likely to affect water quality on undeveloped, forested watersheds (Verry 1986 and Jeffrey 1968 as cited in Rothacher 1970). This alternative deliberately retains an even distribution of

"aggrading" forest, which regulates nutrient export through the rapid accumulation of biomass. It also strives to increase both resistance and resilience in the face of natural disturbances, through the maintenance of age and species diversity. To the extent that this approach limits the impact of these disturbances on the forest, it would also limit their impact on water quality.

The association of water quality impacts and large scale forest disturbances is well-documented. For instance, lake acidification has been correlated with extensive blowdown in several watersheds in New York (Dobson et al. 1990) and nitrogen losses are often associated with natural disturbances such as wind storms, insect defoliations, and fire (Tamm, 1991; Van Miegroet and Johnson, 1993; and Waring and Schlesinger, 1985). Impacts from forest blowdown, or a combination of blowdown and forest fire, can increase tributary nitrate and phosphorus exports to several times background levels (Verry 1986; Packer 1967 as cited in Ottenheimer 1992; McColl and Grigal 1975: Wright 1976; Schindler et al. 1980).

Soil disturbance from blowdown of large numbers of trees may also result in wide-spread erosion (Patric et al. 1984; White et al. 1980 and Swanson 1982, both cited in Ottenheimer, 1992). Ottenheimer concluded that extensive soil disturbance would occur at Quabbin from a severe hurricane, given present forest cover. While the study is one step removed from the direct impacts of disturbance on water quality, Carlson (1994) measured the downed woody material in a 1.6 acre simulated hurricane "pulldown" at the Harvard Forest in Petersham, Massachusetts and found dead material increased from 4.1 tons/ha on the control area to 33.5 tons/ha in the hurricane simulation. He estimated that the flame length of a fire in the hurricane simulation would be twice that of the control and the fire danger would increase as more damaged trees died. The correlation of fire to water quality degradation is well-documented.

Dobson et al. (1990), in reviewing data from hundreds of lakes in New York, New Hampshire and Sweden found strong spatial and temporal associations between percentage of watersheds affected by large blowdown events and long-term lowered pH in basin lakes. They concluded that extensive blowdown alters hydrologic pathways by channeling flow through the "pipes" created by rotting roots so that water is less buffered by subsurface soils and bedrock. Johnson and VanHook (1989), after an extensive watershed study, also emphasized the importance of "macropores" in horizontal and vertical movement of water in forest soils.

By modeling the Quabbin watershed for impacts of a catastrophic hurricane such as occurred in 1938, areas most susceptible to substantial blowdown can be identified. A study of strong hurricane impacts in central New England indicates that winds from strong storms will be from a similar direction (Boose et al. 1993). By implementing Alternative #2 on areas likely to receive the heaviest winds, blowdown damage can be reduced and site recovery will be hastened (see Ottenheimer 1992, Buzzell 1991).

Marks and Bormann (1972) and Vitousek et al (1979) emphasized the importance of regeneration in reducing erosional and nutrient losses after disturbances. McColl and Grigal (1975) concluded that dense, rapid revegetation by aspen suckers after an extensive fire in Minnesota (74,100 suckers/acre 5 months after the fire), was important in reducing phosphorus losses. Bowden et al. (1993) measured changes in soil nitrogen for four months, one year after researchers simulated the effects of a hurricane by pulling down trees on a 1.6 acre mixed hardwood site at Harvard Forest on the Quabbin watershed. They suggested that the rapid reestablishment of vegetation tempered potentially important changes in soil temperature, moisture and nitrogen cycling.

Vitousek et al. (1979) studied soil nitrogen changes in trenched plots where vegetation was removed in 19 study sites around the country, including Harvard Forest. The authors reported three types of responses, each of which delayed leaching of nitrogen to varying degrees. However, without revegetation, all sites leached nitrogen. The speed with which revegetation took place was the crucial element in determining whether nitrogen leached from a site after overstory removal.

There is always a potential association of silvicultural activities with water quality degradation. However, by limiting management to infrequent, partial cuttings and utilizing the most current "best management practices", significant impacts on the key water parameters of turbidity, nutrients, and stream temperature can be avoided during the deliberate disturbances proposed by this Alternative. The perpetual maintenance of multi-layered forest distributed throughout any harvested area limits the potential export of nutrients or sediments released by the harvesting activity. The greatest potential for impacts would generally be from the existing road system, which reinforces the need for regular road maintenance.

d. Impacts Upon Water Quantity

While removal of trees from the forest will generally increase streamflow, Alternative #2 would likely produce only small increases over those in an uncut forest so long as openings are small and distributed within actively growing forest. In general, the surrounding forest will be capable of accommodating the increased availability of both water and nutrients. However, by considering known methods for maximizing water yields from cutting (large group selection cutting of conifers on north-facing slopes with deep unsaturated soils), Alternative #2 can yield more water than an unmanaged, undisturbed forest. On 17 watershed experiments using selection cutting or thinning, an average yield increase of about 1 area-inch resulted (More and Soper 1990; Hibbert, 1967). Douglass and Swank (1972) created a model that predicts that removal of 30% of the forest basal area will yield 2-3 annual area-inches of water or approximately a 10% increase in annual yield at Quabbin for areas treated each year (see Mrazik et al. 1980). Yield increases would be less than in Alternative #1, where increases would probably be on the order of 25% for areas treated (see Hibbert 1967). To the extent that this alternative reduces windthrow, yield (and associated nutrient) increases would be less after a major disturbance than in Alternatives #1 or #3.

Hornbeck et al. (1993) note that changes in species composition can have long-term effects on water yields (for example reducing conifer cover or replacing certain early successional species with late successional species increases water yields). Because the selection systems often favor shade-tolerant species, Alternative #2 would slowly increase the presence of late successional species in some areas, which could increase water yields.

e. Response To Potential Air Pollution Impacts

Quabbin Reservoir's trophic state index (a measure of a water body's nutrient condition) has been placed at the oligatrophic/mesotrophic borderline, a relatively "clean" classification that is primarily threatened by potential phosphate inputs in recent years (MDC, 1988:46 and Sheehan, 1982). However, the accumulating effects of air pollution may present additional threats. Nitrogen saturation, an increasing regional concern in northeastern forest ecosystems, occurs when nitrogen inputs from air pollution exceed an ecosystem's ability, in the short term, to incorporate them. This condition can cause elevated nitrate, aluminum, and hydrogen levels in streams and losses of cation bases from soils

(Van Miegroet and Johnson, 1993). These impacts may be compounded by acid precipitation and ozone pollution (Aber et al. 1989).

Reich and Amundson (1985) found that exposure to average to moderate current U.S. levels of ozone reduced photosynthesis in all species tested (including white pine and red oak) and the authors concluded that current levels of ozone in the eastern U.S. may be reducing photosynthesis over much of the area. These findings may be of special concern because the air monitoring station at Quabbin has recorded among the highest ozone levels in the state. While there may be little that forest management can do to mitigate the direct impact of ozone, its exacerbating effect on nitrate saturation may be mitigated through changes that increase nitrate uptake in the forest. Maintaining biomass and nutrient accumulation in the watershed forest may help reduce impacts of nitrogen saturation, especially where some nitrogen removal occurs through harvesting (Murdoch and Stoddard, 1992; Agren and Bosatta, 1988; Hemond and Eshleman, 1984; Van Miegroet and Johnson, 1993; Skeffington and Wilson, 1988; Waring and Schlesinger, 1985; and Murdoch, 1993, per comm).

Bormann and Likens (1979b) report a doubling in nitrate concentration in precipitation since 1955. Schindler (1988) reports that deposition of nitrogen oxides has increased much more rapidly than that of sulfates in recent decades. An ongoing study at Harvard Forest on nitrogen saturation shows increased foliage nitrogen and increased soil leaching of nitrates on experimental fertilization plots where low and high (50 and 150 kg N/ha/yr respectively) levels of nitrogen have been added (Magill and Aber 1993). Micks et al. (1994) estimated that low and high plots averaged 82% and 92% retention of added nitrogen over three years. This figure would be close to 100% for nitrogen-limited sites in the region - for example Hemond and Eshleman (1984) monitored the Bickford Pond basin in the Ware River watershed for two years and found nitrogen removal was nearly complete, with the lowest monthly retention of 83%).

Analysis of water quality data for 19 Catskill Mountain streams that supply New York City's drinking water show little change in stream water nitrate between 1945 and 1970 but dramatic increases since 1970, even though nitrogen deposition has been fairly constant since 1970. Stoddard (1991) concludes that these stream water nitrate increases are due to a change in the ability of Catskill watersheds to retain atmospheric nitrogen. Although nitrogen deposition and annual precipitation in the Catskills are higher compared with the Quabbin region (Ollinger et al. (1994) place the Quabbin region in the 7.99-9.16 kg N/ha/yr zone and the Catskills in the 10.34-12.66 zone in a model of atmospheric deposition for the northeast), the soils (a mixture of tills and lake deposits) and the climate are similar to those at Quabbin. Net ecosystem production in Catskill hardwood sites is among the highest in the New York-New England region (Ollinger et al. 1994), so that its relative nitrogen retention should also be high, yet stream water nitrates are increasing. A key difference between the Catskill and Quabbin regions is that Catskill forests have not been logged since 1870 and without major fires since 1840. Murdoch and Stoddard (1992) hypothesize that these older forests have a low demand for nitrogen and cannot retain all of the nitrogen being deposited upon them. The New York City water supply tributaries in the Catskills are the site of an extensive research effort to more exactly define the causes of elevated nitrogen (Murdoch, 1993 pers comm).

To put nitrogen deposition figures in perspective, it should be noted that some scientists have agreed that critical nitrogen deposition levels to effect saturation are from 10-20 kg N/ha/yr (Agren and Bosatta, 1988). Other scientists feel a critical load cannot be set due to variations in site conditions such as soil type and vegetation type and age. Due to natural plant community dynamics, nitrogen saturation is described as a "moving target" (Brown et al. 1988). Van Miegroet and Johnson (1993) summarize the complexity of the nitrogen saturation problem: "This soil condition is the

integrated result of vegetation type, age, and vigor, past N accumulation history, climatic conditions, current and past N input regime, and soil characteristics." Aber (1992) presented three generalized annual nitrate stream water concentration trend charts to illustrate nitrogen-saturated, transition, and nitrogen-limited situations. Key indications of potential saturation during the transition period include elevated nitrate levels in spring runoff, even though the summer levels may be still negligible.

Reduced productivity caused by ozone pollution, or increased nitrogen mineralization due to global and soil warming may exacerbate nitrogen leaching (Aber et al. 1989 and Van Miegroet and Johnson, 1993). For example, Aber et al. (1991) predicted that a 10% reduction in net primary productivity due to ozone would cause nitrogen saturation to occur in 50 years versus 300 years without the 10% reduction, for the forest they modeled. Removal of nitrogen, through forest harvesting, may delay the onset of nitrogen saturation, but intensive (esp. whole-tree) harvesting may also reduce other important nutrients. Conversion from species with low nitrogen demand (e.g. pines) to species with higher demand (e.g. oak or maple) may have a measurable effect in reducing nitrogen losses due to nitrogen deposition (Aber et al, 1991). Forests on soils with small nitrogen pools may be more susceptible to saturation than those on fertile soils (Nihlgard 1985). However, Van Miegroet and Johnson (1993) reported that soils whose nitrogen content had been frequently reduced through disturbance had low nitrification potential and nitrate leaching. Elevated nitrates in certain high elevation streams indicate saturation has already been reached there (Aber et al. 1989). The authors conclude: *The environmental effects of nitrogen saturation over large regions could then be considerable in terms of nitrate leaching both to streams and to groundwater.*

Acid deposition can reduce soil fertility, biological activity, and cation-exchange capacity and cause leaching of metals and nitrate from the soil (Smith 1981; Vitousek 1977; Carlton 1990; and Reuss and Johnson, 1986). These processes can cause increased drought stress, winter injury, susceptibility to disease and increased mortality of trees (Petersen and Smith 1989; Klein and Perkins 1988). Soils are critical in determining whether acidification is translated from precipitation into stream waters. Krug and Frink (1983) present a theory that acid soils are more important than acid precipitation in causing acid runoff. However, Reuss and Johnson (1986) note that while natural organic acids produce acid soils, it is only the addition of strong acids (sulfuric and nitric) from acid precipitation that causes leaching through the soil and into stream waters. They describe soils that are susceptible to the effects of acid precipitation as being moderately high in base saturation with very weak cation exchange capacity.

Veneman (1984) classified the buffering capacity of Massachusetts soils with regard to the impacts of acid precipitation. This classification was based upon similar criteria as Reuss and Johnson (1986) with the addition of soil depth to water table (deeper soils are less susceptible to acid deposition impacts). Interestingly, of the 25 soil types that make up almost all of the MDC lands at Quabbin, only four (all wetland soil types) are classified as "acid precipitation will have no negative impact on water quality", whereas sixteen types are listed as "acid precipitation will have a moderate or significant impact on water quality". Baker (1984) re-measured soil parameters at eight sites at Quabbin that had been measured previously in 1962. He found that soils had increased in acidity and exchangeable aluminum and were now releasing sulfate, whereas they were adsorbing sulfate in 1962. This has reduced the neutralization capacity of the soils.

Although sulphur deposition peaked in the 1970's and has been declining since, long-term records at Hubbard Brook, New Hampshire indicate that base cations in stream flow have continued to decrease (from 145 ueq/l in 1963 to 104 ueq/l in 1989) (Driscoll et al. 1989). The authors are concerned that reductions in buffering base cations in precipitation (possibly due to reduced suspended

particulates) may increase the sensitivity of streams, even though sulphur deposition is reduced. Increasing or steady rates of nitrogen deposition may also counter-balance gains in sulphur reductions.

The net effect of air pollution on a forest ecosystem may include a combination of decreased photosynthesis, decreased growth, increased respiration, reduced biomass, and possibly reduced reproduction (Klein and Perkins, 1988 and Reich and Amundson, 1985). Alternative #2 strives to retain well-distributed patches within the forest, which exhibit vigorous net growth and may better retain pollutants in their biomass and soil, and better resist their impacts.

f. Difficulties Involved In Implementation

Careful inventory is required to assure balanced age-classes in intensively managed uneven-aged forests (Arbogast 1985). However, Alternative #2 is a very non-intensive version of the uneven-aged system that works more for multi-layered forests than for perfectly balanced age-classes. Thus, this system would require less inventory and less frequent tending of younger age-classes. The inventory that is required is useful for other reasons, such as tracking species diversity. Leak and Gottsacker (1985) outline new simplified systems for implementing inventory in less intensive uneven-age approaches.

Timber harvesting efforts to maintain the desired structure would also be more difficult than those in even-aged approaches. Trees to be removed would be more widely distributed, rather than concentrated in large blocks. Furthermore, maintaining a diverse, uneven-aged structure requires cutting of trees in the full range of sizes and ages, which further increases the logging effort.

g. Impacts On Non-water Resources

The wildlife community would be dominated by species utilizing forested habitats, with early-successional species limited to the small openings created by this approach. Management may reduce habitat value due to reduced dead and downed material, but sufficient amounts would be retained due to the low intensity of management (long rotations and cutting cycles) and the application of wildlife best management practices. The habitats provided would be the most stable of the three alternatives.

Revenues would be significant in this alternative, but likely less than Alternative #1. Due to the constancy of forest cover, this alternative would be less obtrusive than Alternative #1. Impacts from large disturbances would be less evident and salvage of large amounts of downed material for aesthetics and fire prevention would be easier than in Alternative #3, given existing access within the forest. Due to management, average diameters of older trees would be larger than in Alternative #3.

Alternative #3: Natural Management for Water Quality Protection

a. Description and Underlying Principles

This alternative shares the main Alternative #2 goal of providing long-term protection of water quality. It begins with the premise that an unmanaged Quabbin forest would tend, between major disturbances, toward Bormann and Likens' (1979a) "shifting-mosaic steady state", an equilibrium

condition containing many ages of trees in irregular patches, where "the forces of aggradation and of decomposition would be approximately balanced" and "The forest stand would be considered all-aged and would contain a representation of most species, including some early-successional species, on a continuing basis." (Bormann and Likens 1979a:175). This alternative does not ignore the likelihood of large-scale exogenous disturbance, but proposes that the unmanaged forest will protect water quality from disturbance-related degradation as successfully as the managed forest.

Alternative #3 hypothesizes that the statistical recurrence probability for a truly catastrophic disturbance may be much lower than the 1:100-150 year recurrence generally cited for major hurricanes by Foster (1988b), and that management should reflect this lower probability. This alternative also presents the possibility that, between catastrophic disturbances, the Quabbin forest could gradually meet the increasingly threatened habitat requirements of forest interior wildlife and the conditions generally referred to as "old-growth". In the absence of harvesting, the biomass accumulated in this forest would eventually increase dead and downed material, an important component of old-growth conditions. While acknowledging that the development of old-growth conditions is ancillary to the goals of water supply, Alternative #3 proposes that both goals could be accomplished without significant compromise of either.

An additional goal of this alternative is the eventual cessation of commercial timber harvesting and active wildlife management programs by the MDC at Quabbin. Once the "equilibrium forest" was established, individual trees might still be felled in order to achieve the desired configuration of ecological communities, but this would be accomplished without commercial harvesting. The alternative also hypothesizes that "it is reasonable to assume that old-growth forest conditions will be effective in allowing the ecosystem to hold the deer population in check without a permanent deer hunting program of the type presently underway at Quabbin" (letter from R. Hubley, Mass. Audubon Society, to MDC, 11/30/93). However, this alternative proposes to temporarily utilize both deer impact reduction and commercial timber harvesting for the period required to move the current two-aged, understory-deficient watershed forest more quickly toward the conditions of an all-aged, equilibrium forest.

During the proposed 10-year interim period, "forestry on the watershed should be targeted at structural diversification and understory release activities that would equally serve the goals of Alternative #2 and preparing initiation of natural forest management" (same letter cited above). Silvicultural activities would be similar to those proposed for Alternative #2, but would be eliminated gradually as research showed that the forest had recovered from the effects of many decades of uncontrolled browsing by deer. Due to the complexity of determining where and at what point in time the watershed forest has reached sufficient stability to shift to "natural management", this alternative proposes a much stronger commitment to watershed research aimed at developing a functional array of predictive ecosystem models.

In the perspective of E.P. Odum (1969), ecological succession is "orderly", "directional", and therefore "predictable". Many ecologists have rejected this deterministic perspective, in part because of the prominent role that disturbance plays in the development of most ecosystems (Attiwill 1994; Foster 1988b). Alternative #3 acknowledges the prominence of disturbance in the Quabbin forest, but proposes that the level of disturbance likely in this region poses no greater threat to reservoir water quality than perpetual forest management, and that there is a reasonable chance that an unmanaged Quabbin forest could develop both disturbance-resistance and rare and valuable habitat conditions if major disturbances were absent for 100-200 years.

Like the other alternatives, Alternative #3 would capitalize on the ability of the forest ecosystem to recover from destabilizing disturbances. Studies at Hubbard Brook demonstrated that the northern hardwood forest ecosystem is capable of rapid revegetation following large-scale disturbance. This recovery response includes the accelerated growth of shade-tolerant advance regeneration, the development and growth of stump and root sprouts, and the germination, due directly to disturbance, of dormant, buried seed (Bormann and Likens 1979a). (The latter of these responses, in particular, likely evolved in response to repeated disturbance of the ecosystem.)

Following some initial focussed intervention, Alternative #3 relies upon ecosystem succession and evolution to maintain a level of species diversity that is capable of perpetuating the watershed forest despite the variety of species-specific disturbances that frequent the region's forests. While initial efforts during the proposed 10-year interim period would include the replacement of homogeneous plantations (e.g. red pine) with a more typical, site-appropriate species composition, the forest ecosystem would eventually be left to evolve species diversification in response to environmental change.

This alternative's "natural" management would include small group tree felling on planted pine areas, to encourage diverse, native cover. Contingency plans for monitoring and salvage of dead trees after a major disturbance would need to be considered most carefully for this alternative. Natural management has had little actual application. Several authors note the difficulty in defining management to restore old-growth conditions (see Bolgiano, 1989). However, if the composition, structure, and functional characteristics of old-growth can be defined, management could be utilized to achieve some of these characteristics. For example, Tyrrell and Crow (1994) note that the "old-growthness" of the 100-200 year old stands they studied varied greatly and old-growth characteristics such as tree diameter, tree density, volumes of dead wood, and canopy gap size and occurrence could be manipulated.

Among the important differences between the unmanaged or "naturally managed" forest and one that is subjected to uneven-aged management, may be the size of relatively homogeneous stands that develop. Mladenoff et al. (1993) used GIS analysis to compare the spatial pattern in unaltered old-growth to that in adjacent managed areas in Wisconsin and upper Michigan. This study looked at the distribution and size of "patches", defined as areas of relative homogeneity in size and species composition. Among the findings was that patches of even-aged old-growth hemlock in the undisturbed landscape ranged to more than 2500 acres in size, and 80% of the unmanaged forest was in homogeneous patches greater than 100 acres in size. In the adjacent managed forest, the largest homogeneous patch was just under 400 acres, and 80% of the managed area was in patches less than 60 acres in size and 40% was in patches less than 10 acres in size. The actual figures in the Quabbin watershed will obviously differ on the basis of its intricate and diverse topography, exposure, ground-water, etc., but the comparison still applies. Given a maximum regular regeneration opening of one acre, and the objective of maintaining three layers of different ages, the largest homogeneous patch in the managed Alternative #2 forest could eventually average less than one acre in size.

b. Description of How the Watershed Would Look

As the vast majority of the Quabbin forest is either 50 or 90+ years old, this bi-modal age condition would continue for another 80-120 years (see Bormann and Likens 1979b), assuming no major disturbance occurred. Smaller disturbances - such as insects, small blow-downs or ice storms - would diversify some of this forest. Average tree size would continue to increase but at a decreasing

rate toward the end of this period. The development of an understory layer would be limited to areas where small-scale disturbances occurred (tornadoes, fires, insect/disease outbreaks, ice storms, etc.). While the canopy was intact, the forest would be composed of fairly large trees and an open understory. Once the even-aged forest began breaking up (transition stage), increasing numbers of openings would begin to be filled by forest regeneration. At the end of this transition period, the overall watershed forest would stabilize, with some patches growing older and others being opened by small disturbances (once again, assuming no major disturbance).

If a hurricane like that of 1938 passed through during the first 80-120 years, computer model predictions indicate that the vast majority of the forest would be damaged to some extent (the Harvard Forest hurricane model indicates that 92% of the Quabbin forest is physically "exposed" to such a hurricane, and predicts that at least 70% of the current forest would be 50-100% damaged, and greater than 90% would suffer 25% or greater damage (Ottenheimer 1992)). After 80-120 years without a major disturbance, the impact of a large hurricane might gradually decline as small scale overstory losses brought about a slow increase in the component of young, replacement forest. However, even in the steady-state stage, it's possible that a major hurricane would impact more of the forest cover in Alternative #3 than in the other alternatives described above. Furthermore, the presence of large blocks of homogeneous forest could result in large areas of disturbance in Alternative #3.

c. Impacts Upon Long-Term Water Quality

The basic concept of the steady-state is an equilibrium system in which inputs equal outputs. Assuming no interrupting disturbance, the unmanaged Quabbin forest would likely go through three stages in the next 150-200 years: continued aggradation (nutrients and biomass accumulated) until small, endogenous disturbances (tree death and fall) began to break up the forest, bringing about the transition phase (biomass and nutrients lost), which would eventually settle at a steady-state (biomass and nutrients fluctuate around an equilibrium as new forest openings are balanced by aggradation in older ones) (Bormann and Likens 1979b). Nutrient export would vary accordingly during these three phases. Current data on forest growth and nutrient export at Quabbin conform with the attributes of an aggrading, nutrient-tight system that has yet to reach a transition phase (see below).

For the northern hardwood forest, export of dissolved substances peaks just after a major disturbance, reaches a low point at about 35 years after disturbance, and reaches a second peak at about 200 years after disturbance (Bormann and Likens 1979b). The central hardwood forest would likely follow a related pattern, although the timing might be different. By applying the Bormann and Likens (1979b) stages to data assembled by Lorimer (1977) on original forest cover in northeastern Maine (an area fairly protected from large disturbances), the following is a very approximate breakdown of land in various stages: reorganization (4%), aggradation (37%), transition (32%) and steady state (27%). A stage breakdown similar to this may be expected to occur in central New England, assuming the absence of major disturbances. Measurements in various forests at these stages may help predict the general water quality delivered by unmanaged forests:

Reorganization: In the northern hardwood forest, revegetation following disturbance is rapid. Consequently, the erosion of particulate matter is minimal so long as the site is not highly erodible and the forest floor is not significantly disturbed (Bormann and Likens, 1979a). The biotic regulation of nutrient export is more variable, returning to pre-disturbance levels for nitrates within 1-5 years and for cations in 5-10 years (Bormann and Likens, 1979b). During the years of reduced regulation, nutrient losses from the systems are on the order of 2-12 times those that occur in forests that are in

the aggradation phase (Bormann and Likens, 1979b). Water quality after extensive windthrow and fire confirm that dissolved nutrients and in some cases, sediment, acidity, and total organic carbon can be elevated for several years (Patric 1984 and Swanson 1982 as cited in Ottenheimer 1992; Verry 1986; Schindler et al. 1980; Wright 1976; Corbett and Spencer 1975; McColl and Grigal 1975; Dobson et al. 1990; Dyrness 1965 and McKee 1993 pers comm). For example, nitrates increased by up to nine times and phosphorus by more than three times after extensive windthrow followed the next year by a wildfire in a monitored watershed in Ontario (Schindler et al. 1980).

Aggradation: In general, the aggrading forest ecosystem has the effect of minimizing the transport of dissolved nutrients, through relatively high levels of transpiration and nutrient uptake (Bormann and Likens, 1979b). In addition, the dense foliage, deep, accumulated forest litter, and the high infiltration capacity of the soils, due to dense and deep concentrations of roots, all contribute to the aggrading forest's ability to control sediment and nutrient losses. Average annual sediment yield from an aggrading forest at Hubbard Brook was estimated at 3.3 $t/km^2/yr$, versus 19 $t/km^2/yr$ for a deforested site (Bormann and Likens, 1979b). The 55-year old Hubbard Brook forest accumulated nearly three times more nitrogen and about 50% more phosphorus as was deposited by bulk precipitation (Bormann and Likens, 1979b). It was estimated that only 5% of the inorganic nitrogen that was added to the aggrading forest leaked out of this ecosystem, indicating very "tight" nutrient cycling (Bormann and Likens, 1979b).

Transition-Steady State: As fewer studies have been made of forests in the later stages of ecosystem development (ie. Bormann and Likens' Transition and Steady-state), assessments of erosion and nutrient export are somewhat speculative. In general however, the endogenous disturbance that begins to open the forest during the Transition Phase, and is ultimately balanced with regenerating forest during the Steady-state Phases, is associated with nutrient losses in excess of those in the Aggradation Phase (Bormann and Likens, 1979a). Since the endogenous disturbances of the later stages are generally separated in time and/or space by undisturbed areas, the erosion of particulates is unlikely on all but the most erodible sites (Bormann and Likens, 1979a). Leak and Martin (1975), in New Hampshire, found a correlation between stand age and nitrate discharge and recorded nitrate stream concentrations of .15-.8 parts per million (ppm) for forests 75-125 years of age and 4.8 ppm in an older forest. Vitousek (1977) studied fourteen watersheds in New Hampshire and found old stands averaged 6.62 times the nitrate releases of younger stands. He concluded that steady-state watershed ecosystems use lower concentrations of essential plant nutrients and thus are more "leaky" than rapidly growing intermediate-aged ecosystems. Marks and Bormann (1972) and Vitousek and Reiners (1975) present data that further supports these findings. Nutrient export from older stands is likely in direct relation to the imbalance between portions of the stand that are still aggrading versus areas undergoing reorganization (as a result of treefall or other endogenous disturbance) (Vitousek, 1985).

To the extent that the Lorimer break-down described above is representative of the eventual proportions of various forest stages in an unmanaged Quabbin forest, approximately 60-70% of that forest will be in phases that are less nutrient-retentive than the Aggradation Phase.

d. Impacts Upon Water Quantity

The water yields coming from the Alternative #3 forest are heavily influenced by net forest growth and disturbances. When a previously heavily-logged and burned watershed was set aside as wilderness in New York state (no tree cutting with fire prevention), water yield decreased by 23% in the first 38 years (the combined effects of net forest growth and expansion of beaver wetlands). The

yield on this watershed then increased by approximately 20% due to the effects of an extensive windstorm (Eschner and Satterlund 1965). Streamflow would likely parallel the trend for nutrient export proposed in Bormann and Likens (1979b) - reorganization stage (high yields), aggradation stage (low yields), transition stage (moderate yields) and steady-state stage (low-moderate yields). For the future Quabbin forest under Alternative #3, yields would be stable or would decline slightly over the next several decades (assuming no major disturbance) and would increase to varying degrees once large areas of the forest entered the transition stage and began to break up. If a major disturbance occurred during the next 150 years, water yields would likely be the highest of all alternatives for a short period. For example, Schindler et al. (1980) reported in Ontario that flow increased 50% the first year after a severe wind storm (50% of valley bottom and 100% of hilltop trees blown down) and 70% the following year, after a hot fire burned through the entire watershed.

e. Response To Potential Air Pollution Impacts

Lake acidification has been correlated with extensive blowdown in several watersheds in New York. One lake that received heavy blowdown, but was extensively salvaged, did not acidify, leading the authors to speculate that salvage may partially counter the impacts of blowdown on acidification (Dobson et al. 1990). By reducing the amount of forest cover that is in an active biomass and nutrient accumulation phase and by allowing biomass to decay rather than be harvested, the impacts of nitrogen saturation may be exacerbated (see Aber et al. 1989). Both acid deposition and nitrogen saturation may have serious impacts on central New England forests over the next several decades. The net effect of air pollution on a forest ecosystem may include a combination of decreased photosynthesis, decreased growth, increased respiration, reduced biomass and possible reductions in reproduction. While an unmanaged forest may eventually recover from these impacts, active management deliberately reallocates resources among fewer trees, which increases their resistance to the effects of air pollution.

f. Difficulties Involved In Implementation

All alternatives require that a contingency plan for response to major disturbances be drawn up (just as MDC has completed such analysis and planning for dam failures, hazardous materials spills, and earthquake impacts upon dam stability). Clean up following major wind damage (likely to be called for due to fire danger and safety issues with the visiting public) would be more difficult and dangerous to crews and more difficult with regard to site protection with this alternative, since more trees would likely be involved, and access to clean-up sites would be more limited. In addition, preparations for fire protection during site clean-up would also be more difficult. Historical evidence shows that extensive fires often follow catastrophic blowdowns and fire risk would be greatly increased due to public access (which would occur whether sanctioned or not).

An inherent difficulty posed by adopting this alternative is the cost that would be associated with non-commercial silviculture. The alternative does not propose a complete abandonment of forest survey/inventory, and "natural management" includes the option for "management to promote natural biological diversity" (letter from Mass. Audubon to MDC dated 11/30/93). However, the cessation of commercial harvesting activities means that such management could only occur as an undefrayed expense to watershed management.

g. Impacts on Non-water Resources

For the first 100+/- years (assuming no major disturbance), the wildlife community would be dominated by species utilizing a closed forest habitat, with less understory development. Toward the end of this period (assuming no major disturbance), accumulating dead and downed material and very old trees would offer habitat that is presently uncommon in the region. However, the region has a great deal of forest approaching 100 years currently and it is unclear if any species benefit from 200 versus 100 year old forest habitat (Tyrrell and Crow, 1994). After this period habitat diversity would increase with increased openings and understory development. The forest would have value for research, especially to compare limited management efforts to assist the establishment of a "steady-state" condition to untouched, control areas. Revenues would be minimal in this alternative and research/monitoring and some management costs would still exist. The value of the forest for visitors interested in low intensity management would be high.

2. Evaluation of Alternatives and Selection of a Forest Management Approach

a. Evaluation of Alternatives

A review of three broad alternatives for forest management, based upon relevant research, was presented above. The alternatives considered included an even-age management approach utilizing large forest openings to achieve ACTIVE MANAGEMENT FOR WATER YIELD ENHANCEMENT (ALTERNATIVE #1), an uneven-aged management approach utilizing small openings and resulting in a diverse, multi-storied forest, to maximize ACTIVE MANAGEMENT FOR WATER QUALITY PROTECTION (ALTERNATIVE #2), and an approach that utilizes minimal silviculture to protect water quality by enhancing natural growth and change in the forest, referred to as NATURAL MANAGEMENT FOR WATER QUALITY PROTECTION (ALTERNATIVE #3).

The section that follows compares the ability of these alternatives to meet watershed management goals, discusses some of the areas of uncertainty about their impact on long-term water quality, and summarizes the justifications for selecting an alternative. Throughout this evaluation, the guiding MDC water quality goal is to minimize the long-term cumulative export of nutrients and sediments to the reservoir.

Among the uncertainties facing watershed managers at Quabbin are the frequency and severity of large-scale, exogenous disturbances. The probability of catastrophic wind, to date the most damaging disturbance, revisiting central Massachusetts in any one year is approximately 1:100 to 1:150 (Foster 1988b). Predictions based on records from the past are valuable, but there is wide speculation that the future effects of atmospheric pollution may overshadow historic disturbances. Predictions are further exacerbated by uncertainty regarding the spread of insects and diseases. Consequently, the exact level of diversity required for the Quabbin forest to maintain a stable watershed cover, and thus continue to protect water quality through the range of current and future disturbance and change, is also uncertain.

The Division accepts that any forest, managed or not, may be dramatically impacted by large-scale exogenous disturbance. However, because disturbances often impact specific sizes or species of trees, it seems prudent to adopt a strategy that increases the heterogeneity of the current watershed

landscape in size and species composition. Any given site, on either a managed or an unmanaged forest, cycles between aggradation and reorganization phases (Bormann and Likens, 1979b). Any disturbance that temporarily reduces living biomass (e.g. the death of a single tree) results in a temporary increase in available nutrients. Typically, these nutrients are taken up by adjacent vegetation. However, when some critically-sized patch is disturbed, the ability of forest regrowth and/or the surrounding forest to reclaim these nutrients is exceeded and nutrients are exported to streams (Vitousek, 1985). In the northern hardwood forest, large clearings result in large losses of nutrients for 3-5 years, with some losses continuing for as much as 20 years (Bormann and Likens, 1979b). It is for this reason that Alternative #1, which emphasizes large clearings, and results in the creation of homogeneous blocks of forest, will be less likely to meet MDC's goals for water quality protection if applied generally across the watershed.

Management strategies that produce increased heterogeneity and limit the size of individual openings should accomplish the objectives for disturbance resistance while reducing the likelihood of nutrient export. From Vitousek (1985:333):

> *A final question is, to what extent can vegetation patches within a watershed interact to influence ecosystem-level nutrient dynamics? Nutrients leaching through the soil from disturbed patches toward streams or groundwater could be taken up by adjacent aggrading patches or by riparian vegetation near streams if patch sizes are small and if percolating water is not too deep. In such a case, the watershed as a whole could retain nutrients more effectively than any individual patch, and natural vegetation made up of a mosaic of patches could be significantly more retentive than vegetation managed in large patches.....If these practices are useful and widely applicable, the management of patch dynamics would become an important way to manage the nutrient capital of terrestrial ecosystems.*

Alternative #3 (Natural Management) can result in an "all-aged" forest with a wide range of species represented (Bormann and Likens, 1979b; Lorimer, 1977). Between major disturbances, regular, endogenous disturbances regenerate .5-2% of the temperate forest annually, on average (Runkle, 1985). However, because natural endogenous disturbance is random, areas from several hundred to several thousand acres may remain homogeneous for long periods (Mladenoff et al. 1993), leaving them more susceptible to exogenous disturbance. In a worst case scenario, a catastrophic disturbance striking the Alternative #3 forest would eliminate the overstory from these large blocks, resulting in increases in nutrient export (nitrates, for example) by factors as high as twelve times initially, and continuing to exceed undisturbed export for as long as two decades (Bormann and Likens, 1979b). Such widespread disturbance may also increase turbidity and sedimentation in streams.

The Alternative #2 (Water Quality Protection) approach deliberately enhances the diversity of size and species represented throughout the watershed forest by creating small controlled "disturbances" throughout the watershed. In an ideal application, it would result in the presence of at least three forest layers on any given small forest area, with a range of well-adapted species. Uninterrupted homogeneity would therefore be limited to relatively small patches. Those patches should be large enough to provide conditions conducive to regeneration (i.e., light, nutrients, mineral soil exposure), yet small enough to minimize the export of nutrients and/or sediments from the site. In addition, adjacent, aggrading forest would serve to recapture excess nutrients released by the cutting, preventing their export to the water system. Recapture is further enhanced through the application of "preparatory cutting" to establish regeneration in the understory prior to overstory removal.

The Alternative #2 approach would open approximately 1% of the forest annually, mimicking the background level of .5-2%, described above. Natural tree fall and other small-scale disturbance would obviate the need for harvesting in some areas, but only to the extent that it was evenly distributed across the forest. Where these small-scale disturbances eliminated overstory prior to the establishment of regeneration, supplemental planting would reduce the time required for revegetation. There is no expectation that Alternative #2 could eliminate the randomness of natural disturbance, but promoting diversity of age and species where it does not naturally occur can improve upon the ability of the forest to continue nutrient and sediment regulation despite disturbances.

When large-scale exogenous disturbance eventually strikes the Quabbin forest, research predicts different nutrient export results from each of the different Alternatives. A similarity between Alternative #1 (Water Yield Enhancement) and Alternative #3 (Natural Management) is that each would contain some large, contiguous blocks of even-aged, closed-canopy forest. While this condition has some advantages for deep forest wildlife species, it may be problematic in a watershed protection forest. Once these blocks reach a certain height, they are subject to wholesale windthrow. If they are homogenous in species composition as well, they are susceptible to species-specific disease or insect damage. In some cases, such as root rot fungal attacks, disease weakening may exacerbate the effects of storm damage. As described above, where large areas are disturbed, especially if revegetation is delayed, nutrient releases can exceed the ability of the system to accommodate them. Furthermore, solar regulation, which controls the pace of decomposition and the temperature of streams, is compromised when openings are large.

It is the thesis of Alternative #2 (uneven-aged management) that the proactive diversification of tree sizes and species composition will limit the impact of any disturbance and improve on the system's ability to accommodate any releases that do occur. A severe storm would still topple the taller trees in the Alternative #2 forest, but this would occur in small groups interspersed with groups of shorter, less susceptible trees. A hemlock looper invasion might eliminate that species from sections of the forest, but a wide variety of other species would occur in association with hemlock, and escape damage. The watershed protection forest would persist without lasting or extensive disruption in time or space.

While the New England forest is described as "asbestos" (Attiwill, 1994), and catastrophic fires are relatively uncommon, the large increase in downed material that would accompany catastrophic windthrow would increase the consequences of fires that might start. This threat would clearly be greatest if windthrow were followed by drought. As described in the literature review (in the Supporting Appendices), fire can result in very large nutrient releases, and can greatly diminish the protective function of the forest that is burned.

The potential for large, contiguous, homogeneous areas of forest to concentrate fire fuels reduces the protection offered by the Alternative #1 and #3 forests. While wind or disease killed forest in Alternative #2 could also fuel a fire, these fuels would be dispersed within areas of undamaged forest, which function as a type of fire break. Furthermore, the presence of a maintained access system within the managed forest, and the reduced number of damaged trees in the Alternative #2 forest would make salvage efforts easier. While salvage may not be necessary in all areas, it reduces the biomass that contributes to nutrient-loading and fire fuels, and can speed revegetation (by uncovering mineral soil) if applied properly.

b. Selection of Forest Management Approach

Assuring the protection of a water supply to 2.4 million people in perpetuity is a serious commitment and MDC generally errs on the side of being "over-protective" (for example, in the areas of public access and land acquisition). The Division's management planning process requires the selection of a course of action despite the inherent uncertainty that surrounds its decisions. In the context of watershed forestry, this requirement sets a "working hypothesis" for managing the forest, based upon a conservative interpretation of research and experience. It is the Division's intention to design a forest management plan based on a "least regrets", risk-aversive analysis of the possible consequences of alternatives, in particular as they relate to long-term water quality protection. The Division is committed to re-evaluating management goals and objectives with the writing of future ten-year plans, but adaptations of the current plan, as warranted by new research results, will be incorporated on an annual basis.

MDC has chosen the uneven-aged, species-diverse Alternative #2 approach for its conservative assurance of a disturbance-resistant forest capable of providing nutrient regulation throughout many types of exogenous disturbances. The justification for this choice is summarized as follows:

- This alternative is conservative in that it disturbs the forest at a rate that is approximately equal to the average rate of natural disturbance in the temperate forest (approximately 1%/yr).

- This alternative "improves" upon natural disturbance in that it works to regenerate the forest more evenly across the watershed and more regularly, so that large areas homogeneous in age structure or species composition are less common.

- The absence of large homogeneous areas reduces the overall vulnerability of the watershed forest to size or species-specific exogenous disturbances.

- This alternative works to maintain at least three general layers of forest cover on any given watershed site, including;

  - The understory, which represents a "reserve forest" that is capable, through abundance and resilience, of surviving disturbance and quickly reforesting a disturbed site.

  - The midstory, which provides rapid, vigorous biomass accumulation and regulation of nutrient export (Bormann and Likens "aggradation" stage).

  - The overstory, which gives depth to the forest filter, thus improving its ability to remove air and precipitation-borne pollutants, and regulates solar energy so as to maintain cool tributary water temperatures and slow the decomposition of soil organics, allowing a thick, sponge-like mat of decomposing material to further filter water and protect fragile mineral soils. The overstory is also the most prolific source of seed for the continuous rejuvenation of the forest.

- Having reduced the potential impact of exogenous disturbance on vegetation, this alternative would also reduce the nutrient availability and export that follows such disturbances and that may occur due to air pollution.

• While enhancing the above watershed protection goals, this alternative also maintains access roads throughout the watershed, assures vigilant observations of changes in the forest condition, reduces potential risk from forest fires, and generates revenue; all through the careful utilization of a renewable natural resource.

The Division recognizes that the potential impacts of disturbance and air pollution on water quality will vary depending upon factors such as the proximity of the area to reservoir outlets, the buffering capacity of local soils and vegetation, topography, and the characteristics of tributary drainage. Therefore, while choosing Alternative #2 for general application in the near future, the Division has simultaneously committed to modeling and analysis to begin to identify areas where proactive diversification in the forest cover is most beneficial. This approach will focus forest management on the most important areas, and identify other areas where alternative management approaches could be implemented. For example, on certain "Areas with Special Management Restrictions" (see Section V.A.7), and on disturbance-sheltered areas, an approach that relies more on natural processes would be acceptable, especially if advance regeneration is assured through small natural disturbances, or supplemented by light, occasional management. Likewise, a more even-aged approach, utilizing large openings, might be appropriately applied in areas removed from the reservoir and intakes, in order to increase water yields, wildlife diversity, and/or unusual habitats.

The Division recognizes the need for better understanding of the relationships between water quality and management alternatives. To address this need, the Division will intensify its monitoring of forest conditions and tributary water quality on both managed and unmanaged areas, as described in detail under Section VI.B.8. and VI.B.10. (Forest Research) below. Several islands and the Pottapaug Natural Area provide excellent opportunities to study long-term water quality changes on unmanaged areas. To begin to establish these areas as study sites, the Division will conduct detailed inventories of their flora, fauna and soil conditions during the ten-year management period, and will establish water quality sampling sites within the study areas. In addition, the Division has committed to monitoring of tributary water quality within active timber harvesting areas (Section VI.A.), and is seeking proposals for further study of the long-term impacts of management on tributary water quality. Specific water sampling is proposed to better correlate current tributary water quality with changes in basin vegetation.

While the above analysis focuses on long-range goals, the Division has also evaluated the three alternatives for the ability of each to meet the short-term goal of forest management at Quabbin - the recovery of the regeneration at Quabbin. While the deer impact reduction program is an integral part of this goal, a forest management alternative that methodically allows light into the understory is also necessary in order for the watershed to more quickly recover from decades of intensive deer browsing. The Division has chosen a program that takes a proactive approach to this problem. The land management program is a two part process; first to establish regeneration and then to release regeneration and manage the forest after its establishment. For the majority of Quabbin lands, the second part of the program will occur after the ten years covered by this plan are over.

In this plan, the Division has made a concerted effort to draw on all available information relevant to management decisions at Quabbin. A detailed research program is recommended to help supply additional information in areas where watershed management would most benefit. When dealing with complex natural systems, complete information on present and future conditions will never be available. Watershed managers use available information as "sign posts" to indicate the general direction that appears the safest and most conservative for protecting water supply, even given unknowns.

The Division has actively managed its watershed forests for thirty years with clear benefits and no measurable negative impacts on reservoir water quality, despite changes in priorities and increased monitoring of impacts. This has been accomplished through diligent improvements in Best Management Practices and conservative application of advancing silvicultural knowledge. Adopting a managed, multi-layered forest approach for the next management period is viewed by the Division as a conservative refinement of these practices, applying advances in ecosystem science to the science of watershed management. This approach represents a safe choice whether various air pollution scenarios (acidification, nitrogen saturation, ground-level ozone impacts, global warming and forest changes) worsen or not, or whether catastrophic disturbances (hurricane, insect, disease or fire) occur or not.

3. Description of Forest Management Approach for Ten Years (1995-2004)

a. Objectives for Quabbin Forest Management

The Division has determined that the watershed protection function will be served best by a forest where the majority of acreage is diverse in age, species, and vertical structure, is actively accumulating biomass, and is continuously reproducing.

The Quabbin watershed forest is frequently subjected to natural disturbances, including wind, fire, insects, diseases, animals, and floods. In addition, the majority of the current Quabbin forest consists of 50 or 90-year old even-aged stands with severely limited tree regeneration in the understory, due to 50 years of overbrowsing by white-tailed deer. Without adequate regeneration or graduated vertical structure, the ability of this forest to continuously maintain its protective function following large and/or a series of small natural disturbances may be impaired.

Therefore, the objective of management over the next ten years is to foster regeneration where it is missing. The objective over the next 50-60 years is to enhance age and species diversity on each site, while keeping the majority of the forest cover in a state of active growth (to assist in water and nutrient regulation), through a range of silvicultural practices. This forest will have the resistance capabilities of a "steady-state" forest and the water and nutrient regulation of an "aggrading forest" (See Bormann and Likens 1979b and Vitousek et al. 1981).

In the context of MDC's watershed management, silviculture is applied ecology used in harmony with natural regeneration and succession to create and maintain the watershed protection forest. Note that while silvicultural activities to achieve regeneration and species diversity include commercial harvesting, timber management per se is not the primary objective of MDC's watershed management silviculture. While the Division attempts to achieve superior watershed protection for the water consumer at a reasonable cost, the contribution of timber revenue serves only to reduce the amount of payments from the Massachusetts Water Resources Authority to the Division of Watershed Management and does not increase the funding of the Division. For a discussion of other differences between watershed management and commercial management, see Supporting Appendices: Watershed Management and Uneven-aged Silviculture: A Comparison of Goals and Techniques.

The Quabbin forest management plan for the 1960's (Hunt, 1961) focused on a goal of managing for the best vegetative cover for the watershed given the primary purpose of Quabbin as a drinking water supply. At the time, the Division proposed that an uneven-aged forest represented the best watershed cover. Each successive plan has focused on managing for a protective watershed cover, utilizing uneven-aged forest management on approximately 80% of MDC's holdings within the

watershed, but the plans in the 1970's and 1980's added secondary goals of increasing water yields and diversifying wildlife habitat.

This (1995-2004) plan once again focuses primarily upon managing for the most stable and protective watershed cover possible. The new plan will implement a computer modeling approach, described below as "sub-basin analysis" (Section V.E.), for locating areas that are clearly less important to this primary goal in order to concentrate secondary uses on the areas that are least critical to watershed protection. This analysis will also locate areas where active forest management activities are most critical to water quality protection.

Textbooks on silviculture describe the variations between methods within the even-aged and uneven-aged systems. However, the technicalities involved in naming the method are less important than describing the condition of the forest that such management will maintain. At Quabbin, the "protection" forest will be as diverse in tree ages, sizes, and species composition as the local site conditions allow. This will mean that the filtering capabilities and stability of the forest, on the local and watershed level, are optimized by balancing the objective of maintaining several layers of forest cover with that of maintaining active forest reproduction and growth.

Note that between major natural disturbances, Quabbin forest management will concentrate on manipulating approximately two-thirds of the forest area to maintain an understory and a midstory component within the overall forest. The young, dense understory primarily functions as a "reserve" forest, capable of immediately renewing forest cover following a damaging disturbance. The primary value of the midstory is its ability to aggressively assimilate nutrients as it accumulates biomass.

The age at which a forest layer will move out of the understory and into the midstory, or out of the midstory and into the overstory, is obviously variable. However, studies have shown that a northern temperate forest continues to accumulate biomass, first quite rapidly and then more gradually, until about year 50-60 (Bormann and Likens, 1979b). Beyond this point, the ratio of respiratory to photosynthetic tissues increases, so that net accumulations slow. Based on this information, the Division plans to maintain a 0-30 year old understory component on one-third of the managed forest, and another third in 30-60 year old midstory.

Over the sixty years required to secure understory and midstory components throughout the watershed, one third of the overall forest will continue to grow and mature, unless it succumbs to natural mortality. The silvicultural goal for the next sixty years is to increase resilience, and to improve nutrient uptake, by carefully distributing younger layers throughout the watershed forest. This goal does not mandate that every disturbance-susceptible tree be replaced, but rather that it be balanced, in the overall landscape, with disturbance-resistant trees.

MDC controls more than 57,000 acres of land surrounding Quabbin Reservoir, of which approximately 10,000 are under "special management restrictions" (see Section V.A.7. above). Therefore, the objective is to create a forest composed of one-third 0-30 year old understory, one-third 30-60 year old midstory, and one-third older trees on 47,000+ acres. To accomplish this objective, once the forest has regained the ability to regenerate, approximately one-third of the 47,000 acres will be regenerated every thirty years (see Figure 9.). Since the objective is to evenly distribute this regeneration across the forest, approximately 1,500 acres per year will be treated, with regeneration cutting on approximately 500 of those 1,500 acres, on average. At this pace, approximately 15,000 acres, or one-third of the forest, will be regenerated every thirty years, distributed throughout the 47,000 acres under active management.

The present forest condition and composition will dictate the actual amount of time required to fully implement the protection forest. There is little specific guidance in the literature for timing the recovery of a forest ecosystem that has been heavily browsed for more than fifty years. The MDC approach will therefore be conservative, working to establish regeneration of a diversity of long-lived, site-suited species before proceeding to release developing regeneration. Some areas will require periods of waiting (for seeds to fall and germinate), "preparatory cuts" to establish regeneration by bringing light and heat (to decompose humus and release nutrients) to the forest floor, and/or enrichment planting to make up more quickly for deficiencies in the understory. Deer browsing control is an assumed condition of this recovery. Once the understory has recovered to species well-suited to the site, cuts aimed at releasing developing regeneration will proceed.

While most of the proposed regeneration silviculture, which will follow the recovery period, can be classified within the single tree and group selection methods of the uneven-aged systems, the irregular shelterwood method (a hybrid with attributes of both uneven-aged and even-aged systems) may also be applied where appropriate. The guiding criteria for any silviculture applied on the watershed will be its ability to maintain a "reserve forest" in the understory, and an actively growing overstory. Again, see Supporting Appendices: Watershed Management and Uneven-aged Silviculture: A Comparison of Goals and Techniques.

b. The Role of Natural Disturbance

Natural disturbances impact all sites where trees grow. They can be localized, such as small-scale fires and storms, or cover large areas, such as insect defoliations, deer browsing, beaver activities, floods, or catastrophic fires and hurricanes. Management activities recommended in this plan attempt to mitigate the effects of both small and large-scale disturbances in the riparian zone and large-scale disturbances of the uplands.

For the past 40 years, the greatest impact to the upland understory has been over-browsing by deer, with moderate to severe impacts on 37,000 acres inside the Reservation. Important natural disturbances of the overstory during the same period included insect defoliations, which caused mortality in the oak forest throughout the watershed, and destructive windstorms. Within the past 30 years, the greatest alteration of the riparian zone has been caused by the flooding and tree-cutting activities of beaver and the reduction of tree regeneration through deer browsing. This combination resulted in the deforestation of an estimated 2,000 riparian acres.

Historically, the greatest natural disturbance of the overstory in New England has resulted from catastrophic wind storms such as the 1938 hurricane. Hurricane studies at Harvard Forest in Petersham, MA (Foster and Boose 1992) indicate that conifers are more susceptible to windthrow than hardwoods and some sites sustain a higher incidence of damage. Conifers greater than 34 feet tall and hardwoods greater than 74 feet tall received severe damage (>75% of all trees were damaged) on nearly level sites (<5 degrees) or slopes oriented to a windward direction (S,SE,E); and intermediate damage (50-75% of all trees were damaged) on mild leeward slopes (5-10 degrees, N,NW,W) or intermediate orientation (NE,SW,>5 degrees). Hardwoods greater than 64 feet tall on these same exposures are damaged 51-75% and 25-50%, respectively.

Approximately 80% of Quabbin's forest presently meets or exceeds the combination of conditions that would result in severe (>75%) or intermediate (50-75%) damage to the overstory were a storm similar to the hurricane of 1938 to occur. While it is impossible to know the exact path of the

next New England hurricane, the variety of paths of past New England hurricanes has been limited (David Foster, Harvard Forest, personal communication - 1993). Ottenheimer's (1992) application of the Harvard Forest hurricane damage model to Quabbin indicates that 91% of the MDC-owned Quabbin watershed is considered physically "exposed" or "intermediate" (Figure 7). The current forest overstory on much of the Reservation is composed of single-aged hardwood, softwood, and mixed stands, of which only a few hundred acres of hardwoods are less than 64 feet in height, and less than 1% of the softwood stocking is shorter than 34 feet. On the off-Reservation lands, where deer have been hunted and regeneration is abundant, management has begun to achieve the objective of a multi-layered forest structure, which is capable of more rapid recovery from hurricane impacts than the even-aged forest.

Based on the application of the Harvard Forest model to Quabbin forest conditions (Ottenheimer 1992), the Division estimates that a catastrophic windstorm similar to the 1938 hurricane would uproot or snap off greater than 75% of the conifers and 50-75% of the hardwoods on 37,000 acres of exposed sites, and 50-75% of the conifers and 25-50% of the hardwoods on 13,000 acres of intermediate sites.

In December of 1992, the Director of the National Hurricane Center announced that, beginning in 1985, the East Coast entered a new phase of heavy hurricane activity, related in part to weather activity over Africa. Hurricane Andrew and several lesser hurricanes were an expression of this trend.

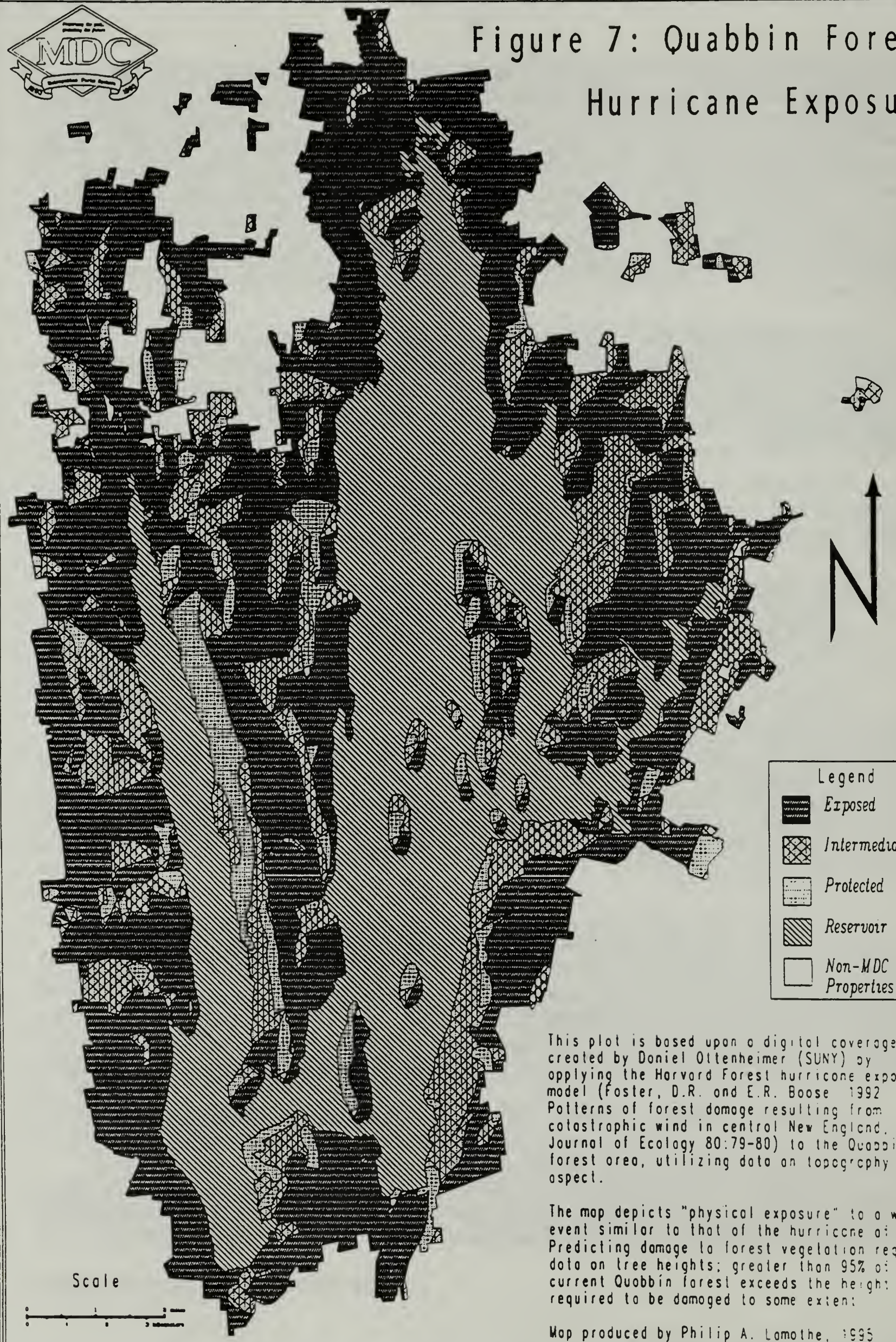
> *From meteorological records and forest reconstructions it has been estimated that hurricanes strike southern and central New England every 20-40 years, while catastrophic storms like those of 1635, 1788, 1815, and 1938 occur approximately every 100-150 years.* (Foster 1988b)

While the frequency of occurrence of catastrophic winds in New England cannot be changed, the resistance and resilience of a forest to such impacts can be enhanced by the purposeful distribution of a diversity of tree sizes and species across the landscape. The structure proposed by the long-range silvicultural objectives for the Quabbin forest would greatly reduce the present damage risk predicted by the Harvard Forest hurricane model, in that as much as two-thirds of the forest on exposed areas would be below the critical damage heights. This lower level of impact would allow for much of the forest that was damaged to be salvaged, which would in turn reduce fire hazard and subsequent nutrient losses to the reservoir.

It is important to point out that although the Harvard hurricane model indicates that nearly 50,000 acres of the current forest would be at risk in the face of a major hurricane, this does not necessarily equate to a water quality risk everywhere. One of the most important results of the sub-basin analysis that the Division is conducting will be to refine the focus on gross risks, such as storm damage, to the specific risk, which is related to such variables as the proximity of the area to the Reservoir, the gradient of the slope, and the characteristics of the understory. It is upon this last variable that the forest management program at Quabbin can have the most extensive positive impact.

An important impact to the riparian zone throughout history has been catastrophic flooding. Studies show that the scouring that occurs during large infrequent storms contributes the majority of annual outputs of sediments and some nutrients (see for example, Meyer and Likens 1979). Such flooding occurring on the current Quabbin landscape could breach beaver dams along streams, possibly releasing large amounts of sediments and organic material that have accumulated behind the dams. The amount of material washed downstream in these events might be reduced if unstable beaver dams

Figure 7: Quabbin Forest Hurricane Exposure



This plot is based upon a digital coverage created by Daniel Ottenheimer (SUNY) by applying the Harvard Forest hurricane exposure model (Foster, D.R. and E.R. Boose 1992 Patterns of forest damage resulting from catastrophic wind in central New England, USA Journal of Ecology 80:79-80) to the Quabbin forest area, utilizing data on topography and aspect.

The map depicts "physical exposure" to a wind event similar to that of the hurricane of 1938 Predicting damage to forest vegetation requires data on tree heights; greater than 95% of the current Quabbin forest exceeds the height required to be damaged to some extent

Map produced by Philip A. Lamothe, 1995

were stabilized, or if beaver-impacted areas were regenerated to dense forest cover. Unstable beaver dams are addressed in Section V.C.3.b.

c. Soils/species Suitability

Although many Quabbin stands are established on sites suited to their long-term growth and development, some are not. Most older stands are the result of past land uses 70-100 years ago, whereas younger stands are the result of the 1938 hurricane and MDC tree planting 50-60 years ago. Severe disturbances coupled with heavy deer browsing, as well as off-site plantings done in the 1930's and 1940's, have produced species/soil combinations poorly suited to long-term vigor and stability. The most pronounced examples are red and white pine plantations on poorly-drained soils and birch/red maple stands that developed under the influence of grazing (both of these are prone to blowdown and various diseases). Both of these sites would support a diversity of long-lived, low-maintenance hardwoods if allowed to develop without excessive browsing/grazing. It is one of the objectives of forest management on the Quabbin to identify stable soil/species combinations and to encourage their development through silvicultural operations.

d. Analysis of Quabbin Forest Regeneration

1) Introduction

It has been repeated throughout this management plan that recovering the regenerating potential of the forest is an important land management objective at Quabbin over the next ten years. Regeneration anchors soils following disturbances, resists damage from many disturbances (due to size and density), assimilates nutrients more rapidly than older vegetation, and shortens recovery times for reestablishing forests following disturbances. The combination of large, contiguous blocks of mature forest lacking in understory development and threats posed by air pollution, insects, disease, and wind, could reduce the future ability of the forest to continuously protect the Quabbin Reservoir. Where trees die without replacement, the Quabbin forest becomes increasingly more open and may be less effective in protecting the reservoir in the long-term (see Carlton (1990) for example).

The absence of regeneration provided the impetus for initiating deer impact control, primarily through controlled hunting. Division foresters have prepared reports on the condition of regeneration throughout the watershed as evidence of the impact of deer on that regeneration (Kyker-Snowman 1989; and follow-up reports in successive years since). Division foresters also have established permanent plots of various designs to continually monitor regeneration development, and the evidence of the evolving understory will be documented throughout this management period.

Regeneration success relies on seed sources, appropriate seedbed conditions for germination and initial establishment, and good conditions for development of the established seedlings. What follows is a discussion of some of the challenges facing managers in effecting this process in the Quabbin forest.

2) Seed sources

The vast majority of the trees in the overstory of the Quabbin forest are of seed-bearing age, so that in general there is no deficiency of tree seed. Seed production is variable on an annual basis, due to both species differences and weather conditions. In general, shade intolerant species produce

seed with fewer years between crops than the more shade tolerant, slower growing species. The birches, for instance, produce seed every year, with bumper crops every two years, while sugar maple bumper crops may be 5-7 years apart. Greater than 50% of the Quabbin forest cover is composed of white pine and white or red oaks, all of which produce seed in somewhat regular cycles. White pine requires a full year of development between pollination and fertilization, and good cone and seed years occur every 3-7 years. Red oak acorns require two years to mature, and good seed years occur on average every 2-5 years. White oak acorns mature in just 120 days, but good seed years occur only every 4-10 years (USDA 1990:607-8).

Weather influences seed production in a variety of ways. Flowering can be disrupted by periods of freezing weather or high winds, and pollen shedding may be delayed by excessively wet weather. Flowering is also clearly influenced by the general vigor of the individual tree - open grown trees generally flower more productively, and so are potentially more prolific seed producers. The management implication is that maintenance of vigor will help to ensure seed production.

Vigorous trees of seed-bearing age can produce phenomenal quantities of seed. A single 12" diameter (at 4.5') red maple may produce nearly one million seeds in a seed year, and birch stands frequently produce 20 to 35 million seeds per acre (Burns and Honkala, 1990). Even the large-seeded oaks are capable of producing 200,000 acorns per acre in a good seed year (Burns and Honkala, 1990). However, survival percent is extremely low for most seeds for a variety of reasons. Small seeds tend to be fragile in their ability to withstand moisture and temperature extremes. Acorns, the largest seeds, are an important food source for wildlife, which can consume nearly 100% of the crop in some years (Spurr and Barnes 1980:353), and for insects such as the acorn weevil (Marquis et al. 1976).

3) Seedbed Conditions and Initial Establishment

Specific germination requirements for tree seeds are variable by species. Most adapt to poor conditions for germination by entering a period of dormancy until conditions improve. Red oak acorns must pass through a period of low temperatures before they will germinate. White oak acorns germinate the same year they fall, but only the root grows, while the shoot remains dormant until it passes through the winter. Most seeds cannot break dormancy until specific moisture requirements are met. Because weather is the most critical determinant, there is little that management can do to improve initial germination, although overstory density exerts some control over seedbed moisture.

The greatest mortality rate for trees occurs immediately following germination. Moisture and temperature conditions sufficient for germination may not persist to support establishment. All seedlings are initially succulent, and consequently susceptible to fungal attacks. The simple length of the initial root radicle can allow some species (e.g., sugar maple) to reach moist mineral soil while others (e.g., yellow birch) fail to penetrate deep duff and succumb to desiccation.

Division foresters employ various methods of scarification to expose mineral soil and enhance seedling establishment, accomplished primarily during logging operations. Effective scarification reduces understory competition, brings seeds into direct contact with mineral soil, and reduces seed predation by reducing the protective cover provided by forest litter. On the other hand, scarification exposes seed to predation by larger animals such as deer or turkey, so that it becomes critical that some seed is completely buried in mineral soil. At this point, deliberate scarification (other than that occurring as a result of logging) is still experimental on the watershed and not proposed for large-scale application.

4) Development

It has been estimated that of the 15,000 sugar maple seedlings that would initially be established in the gap created by the death of a single large tree, only 150 would remain after three years, and eventually only one or two mature trees would occupy the gap (Curtis 1959). It is this early, rapid reduction of numbers that leads foresters to consider regeneration as "established" only after it has survived the first several years, successfully adapting to its immediate environment. Many species are not considered likely components of the future overstory until their seedlings survive to heights of 4-6' (well established and out of the range of browsers).

Establishment ecology varies with both site conditions and plant community composition. At Quabbin, high deer populations affect community composition both directly, through browsing, and by enhancing the competing herbaceous component, especially ferns. On the 796 1/1000th acre regeneration plots inventoried in 1989, 199 (25%) included the presence of ferns, 48 of which (6%) had "heavy ferns". On regeneration plots taken in 1993, 16% were classified as containing sufficient ferns to inhibit forest regeneration. To the extent that these 1993 plots represent the Quabbin as a whole, regeneration on approximately 9,000 (.16 x 57,000) acres may be restricted by fern competition to some extent. Following deer control, the reduction of herbaceous competition will be important for improving tree seedling development at Quabbin.

The importance of "brambles" (*Rubus* spp.) in competing with ferns and opening up sites for tree development has been documented (Horsley and Marquis 1982). Deer impact reduction will enhance *Rubus* development, but it was demonstrated in Pennsylvania that sites with 30% or greater fern cover continue to have dense fern cover even after deer populations are reduced (Marquis et al. 1975). The existence and persistence of allelopathic chemicals associated with ferns (that can inhibit tree growth) may also be a factor. Much of the research on fern reduction has included application of herbicides, which is not an option on the Quabbin watershed. Division foresters are experimenting with scarifying dense ferns and planting fast-growing tree species with protective shelters to compete with and eventually shade out herbaceous competitors.

Where herbaceous competition is not limiting, the establishment ecology of the plant community will vary with site conditions - especially light availability - and the composition of the seed sources. Shade tolerant species are photosynthetically most efficient at low light levels, and begin to photosynthesize at very low light levels. They survive to become part of the overstory by "idling" along in the understory, making gains as surrounding trees die or are removed. Shade intolerants, on the other hand, are most efficient at high light levels, and able to grow quickly when light is unlimited. In ideal conditions, paper birch has reached 16.5" in the same year as germination (USDA 1990:162), while hemlock beneath a dense overstory may take decades to reach this height.

Much of forest management is focused on manipulating the establishment ecology of trees. At Quabbin, especially where hunting has not been allowed, deer browsing and the distribution of species in the overstory have exerted strong influence over this ecology. A few examples of this influence are discussed below.

Quabbin is known for its large, contiguous blocks of oak-dominated forest. High deer populations clearly influence the future of the oak component, through acorn consumption and direct browsing of seedlings, but the ability of oaks to survive will be influenced by developmental characteristics even after deer are reduced.

The survival of oaks relies, in part, on early allocation of photosynthate to root structures. While this may limit height growth, it builds a platform from which oaks can continually resprout, should the primary shoot be damaged. This ability allows young oaks to survive fire better than other species. If an intense fire sweeps through the understory, it may kill back all tree species. Conifers do not resprout, and even hardwoods that sprout following cutting and light fire are unable to recover from intense fire. Oaks are the exception to this due in large part to the early development of their roots.

It is widely accepted that fire played a part in the establishment of many of New England's oak forests. The emphasis on preventing fire may also inhibit the regeneration of oak on the watershed. The Division is experimenting on a very limited basis with using controlled burning to stimulate vigorous resprouting of oak seedlings that have been continually browsed but are still capable of response. Coupled with deer browsing reduction, this practice may retain oak as an important component of the future watershed forest. However, it is not likely that management will be able to reproduce Quabbin's large, contiguous blocks of oak forest, nor is this desirable for watershed protection, in that it represents low species diversity.

White pine is the second largest component of the current Quabbin overstory. It is intermediate in shade tolerance, and capable of germinating and surviving on a wide variety of sites. It typically competes best on drier sites, where other common species (mostly hardwoods) do not grow well under moisture stress. On the other hand, it grows more vigorously where moisture is less limited, where it typically has to compete with hardwoods. However, its vigor on these sites is reduced by the more frequent attacks of fungal diseases and insects.

As a food source, white pine is less preferred by deer than its hardwood associates, allowing it to become well established at Quabbin on both dry and moist sites where deer numbers have been moderately high. Where deer numbers are higher, white pine is included in the deer diet and its establishment is reduced or prevented (e.g., on the southern tip of Prescott Peninsula). The Division's silvicultural practices have taken advantage of the ability to establish white pine on moist sites where deer numbers are high enough to browse competing hardwoods but not high enough to significantly impact white pine regeneration. For this reason, it seems likely that white pine will increase its percentage of the overstory for at least the next 50-100 years.

Black birch has long been known to successfully capitalize on forest openings in Massachusetts, especially well-scarified sites such as skid trails and landings. Because black birch is capable of rapid height growth where light is unlimited, and because it is less preferred as deer browse, it has become established on sites within the Reservation where virtually no other species has become established. In MDC's 1989 regeneration study, approximately 25% of the non-hunted sample area contained 1000 or more stems per acre of black birch greater than one foot in height. This situation has assured the presence of black birch in the future overstory at Quabbin, although its susceptibility to *Nectria* fungi limits its longevity in this region.

5) Management Concerns

The occurrence of black birch regeneration raises the more general question of the future role of silviculture in directing the composition of the Quabbin forest overstory. Among the strongest reasons for managing forest succession is the desire to create and continually reproduce a low-maintenance, protection forest. Where short-lived, "pioneer" species become established, watershed management may require early and frequent intervention to replace trees as they decline.

On the other hand, if early establishment ecology can be manipulated to favor long-lived species such as hemlock or oak, overstory retention should require less frequent intervention.

The MDC defined "adequate regeneration" in its 1991 Deer Impact Management Plan (MDC 1991:12), in order to specify what is meant by "success" in efforts to recover a Quabbin understory. Acceptable regeneration levels were based on estimates of the number of seedling/saplings necessary to regenerate a forest following disturbance. That estimate is based upon regeneration literature reviewed by Kyker-Snowman (1989) and on measured averages in areas off-Reservation with sufficient light to support regeneration (i.e., areas that had been disturbed either naturally or silviculturally). Adequate regeneration is thus defined as the establishment of at least 2000 stems per acre of seedlings/saplings greater than 4.5 feet in height, with a diverse species distribution including components of hemlock, pine, oak, birch, and maple.

e. Silvicultural Practices

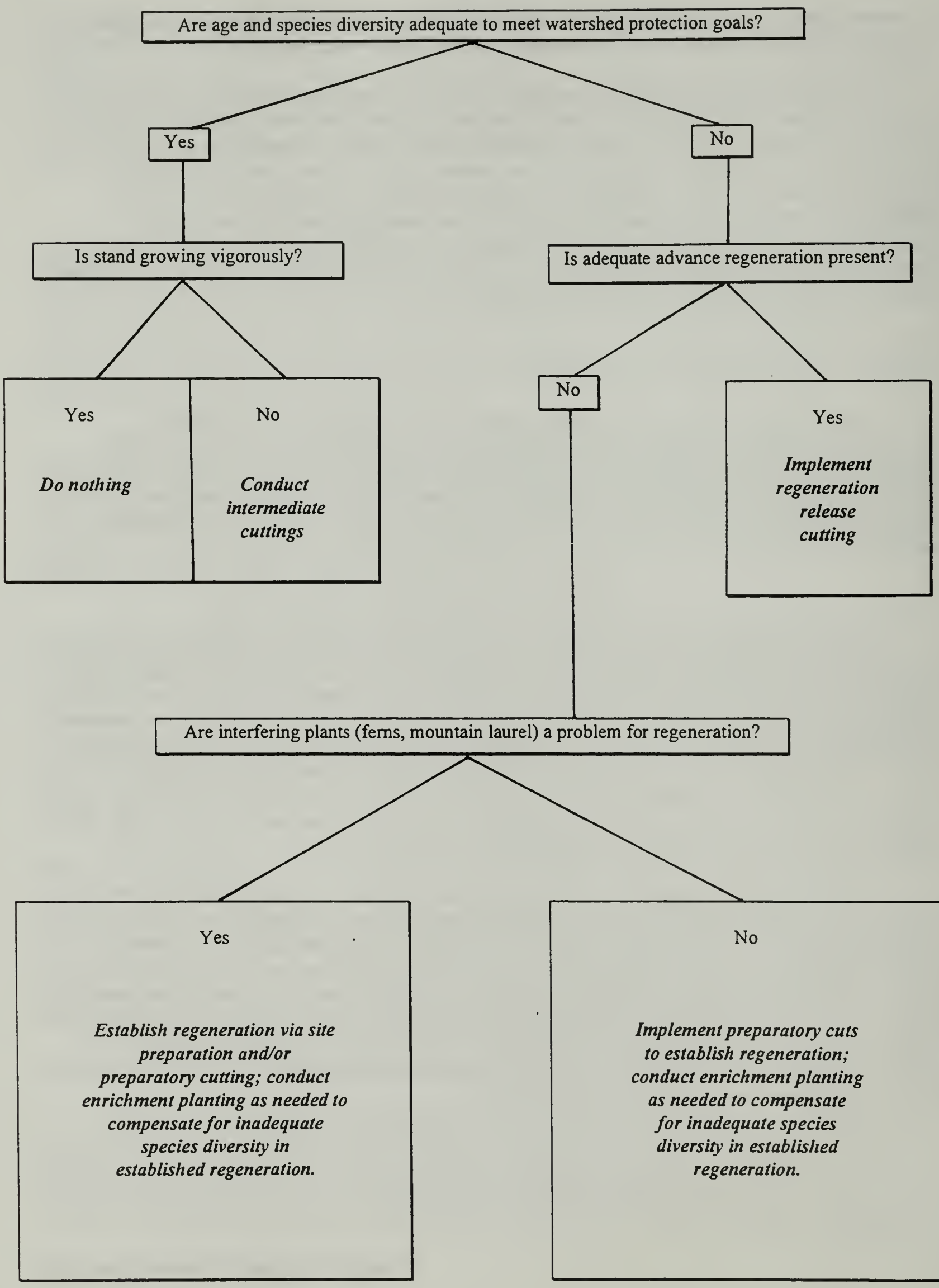
Figure 8 outlines the decision-making strategy Division foresters follow to determine appropriate silviculture in an area. The principal management objective during this period is the recovery of the regeneration process across the previously unhunted portions of the forest. Once this recovery is clearly evident, the long-range goals of increased diversity of ages and species will be pursued. The fundamental silvicultural methods the Division will use to achieve these objectives are detailed below.

1) Regeneration Establishment: Preparatory Cutting

As mentioned above, it will be difficult to predict the pace of understory recovery in areas of Quabbin that have been heavily browsed for many decades. Some of these areas have been thinned during past management periods so that light and seedbed conditions are sufficient to allow forest reproduction once deer control is in effect. Other areas either have not been treated or have re-closed their canopies so that additional treatment is needed to bring sufficient light (and heat) to the forest floor. Where the latter condition exists, initial silviculture during this decade will consist of "preparatory" cuttings. Preparatory cuttings remove just as many trees, generally from lower crown classes, as needed in order to enhance the seed-bearing success of the remaining overstory trees, and to bring sunlight to the forest floor in order to establish regeneration.

While preparatory cutting is most commonly associated with even-aged silviculture, its objectives are similar to those for recovering tree reproduction in the Quabbin forest. In conventional silviculture, preparatory cuts are often employed to increase the vigor and thus the seed bearing capacity of desirable seed trees, and/or to improve the seedbed conditions beneath these seed trees. Much of the Quabbin overstory is composed of vigorous seed producers, maintained through multiple thinnings. Therefore, the primary objective of preparatory cutting will be to bring moderate levels of light and heat to the forest floor, to promote the germination and survival of tree seedlings. Once forest reproduction has recovered, the managers choice of silvicultural methods will determine whether the forest develops even or uneven-aged characteristics.

Figure 8: Silvicultural Decision-Making Chart


Are age and species diversity adequate to meet watershed protection goals?
Yes
No
Is stand growing vigorously?
Is adequate advance regeneration present?
Yes
No
Do nothing
Conduct intermediate cuttings
No
Yes
Implement regeneration release cutting
Are interfering plants (ferns, mountain laurel) a problem for regeneration?
Yes
No
Establish regeneration via site preparation and/or preparatory cutting; conduct enrichment planting as needed to compensate for inadequate species diversity in established regeneration.
Implement preparatory cuts to establish regeneration; conduct enrichment planting as needed to compensate for inadequate species diversity in established regeneration.

2) Regeneration Establishment: Site Preparation and Enrichment Planting

Site preparation may be required where plants such as ferns, huckleberries, or laurel are interfering with tree regeneration. Site preparation treatments consist of "scarifying" (breaking up) the ground cover and exposing small areas of mineral soil to allow for the establishment of trees and shrubs among dense herbaceous species. This can be done as part of silvicultural operations, for instance by pushing slash into piles, or it can be accomplished as a separate operation in mature stands. Site preparation is needed primarily to reverse the effects of prolonged over-browsing, and should be less important in the future. In all cases, it will be carefully controlled to avoid erosional impacts. Abundant surface stones, steep slopes, or wet soils may prevent ordinary site preparation methods. In these cases, planting, controlled burning, or simply waiting for regeneration to slowly develop are possible solutions to herbaceous competition.

Natural regeneration is the preferred source of the new forest development, and is expected to meet most regeneration objectives within 5-15 years after deer impacts have been reduced. However, on some sites with established herbaceous competition, enrichment planting may be employed to hasten the establishment of the understory forest.

> *In temperate forests, enrichment is often done by setting young trees of principal species at wide spacing among existing forest growth, which may be natural or planted. Like improvement fellings, enrichment is a preparatory stage in the progress toward a full silvicultural system.* (Matthews 1989:230)

Replacing herbaceous cover with long-lived trees will improve soil porosity and infiltration, and therefore reduce the potential for overland flow. This is especially important along stream banks, where root systems bind soils in place and reduce the potential for erosion. Native species best suited to the soils found in the riparian zone will be planted as needed in these areas. On a limited basis, these enrichment plantings will be protected with tree shelters, in order to assist their development. The Division has planted approximately 50,000 seedlings per year over the past 10 years, primarily white pine underplanting on dry oak sites subject to gypsy moth damage. Riparian plantings will be in addition to past planting levels and may involve larger stock and a greater variety of species, including hemlock and spruce.

3) Release of Regeneration

The Division's silvicultural practices will accommodate the complexities of sites, species, space, and time needed to transform the current even-aged forest to a multi-layered, uneven-aged forest. This "protection" forest will be established by using variations of the selection and shelterwood systems. These silvicultural practices will be aimed initially at establishing the regeneration needed to diversify stand structure and species composition. Regeneration cutting then removes sufficient portions of the overstory trees to release desirable, established regeneration so that it is free to grow, while also improving the vigor of the remaining overstory trees.

In practice, the cutting cycle in any given area will average 20-30 years, using a variety of silvicultural techniques adapted to individual stand needs. Most stands will be treated with *selection* methods, removing trees singly or in small groups (generally 1/10 to 1/4 acre in size, but up to 1 acre, in order to accommodate the range of shade tolerance among species). In limited areas, where it is desirable to convert "poorly-sited" species to a more resilient composition, removal of entire stand

overstories will be considered once the understory is well established. Full overstory removal on areas greater than one acre will not be common practice (less than 1% of the managed forest), but will be used in initial stages of the management period where the understory composition meets the objectives for a stable cover better than the existing overstory. Three specific situations meet this criteria:

1. *Pine plantations on mesic hardwood sites.* These sites are prone to fungal invasion and spread in planted pines, for instance by root-rotting *Fomes annosus*, and to increased windthrow due to a poor root:height ratio. Due to the generally moist soils, regeneration by native hardwoods is reliable and rapid in areas where deer browsing is controlled, and results in a more resistant, more diverse cover of locally native species.

2. *Red maple/birch stands on mesic sites that were heavily grazed by livestock during overstory establishment.* Livestock grazing greatly reduced future overstory species diversity on these sites, generally by allowing only shade intolerant, pioneer species to grow (these grow quickly enough to have escaped grazing). These species have adapted to frequent disturbance with short, rapid cycles of growth and reproduction. It is common on these sites for the crowns of red maple and black birch to show signs of frequent damage due to the combination of weak form, fungal infections and storm effects. Furthermore, when severe winds strike these stands, the overstory is prone to windthrow and uprooting, potentially exposing large areas of soil to erosion. For watershed protection purposes, the promotion of long-lived species that produce low-maintenance stands on sites that will support them is preferred.

3. *Old fields that have regenerated predominantly to "pasture pine".* White pine is one of the few species able to seed into grass cover and survive competition for water during dry periods (Spurr and Barnes 1980:444). Consequently, abandoned fields have regenerated to homogeneous white pine cover on some areas. As they establish in open conditions and relatively low densities, these stands attract the white pine weevil and tend to develop weak branching that is subject to ice and snow damage. The combination of low species diversity and damage susceptibility creates high maintenance stands that are difficult to manage efficiently. Once the original grass cover has been replaced with forest litter, removing these stands allows for their replacement with a more diverse, resistant, forest-grown composition.

To the extent that it produces the desired multi-layered forest more efficiently than the selection methods, the *irregular shelterwood* method will be employed on the watershed. The irregular shelterwood method differs from standard shelterwood practices in at least two ways:

1. the overstory is removed more gradually, through the expansion of initial openings, so that the removal/replacement of the overstory takes considerably longer than 20% of the rotation (the convention for standard shelterwood - see Smith (1986:409)), and

2. the result of this protracted removal is that the stand contains two layers (technically "even-aged") for longer periods of time, and furthermore, the younger layer develops height variation which mimics uneven-aged structure (Smith 1986:414)

Among the advantages of both the selection and the irregular shelterwood systems is the flexibility they provide the managers to adapt silvicultural objectives to the range of sites presented and the variety of species to be reproduced (Matthews 1989:136 and 181).

One objective of the Division's forest management is to increase the diversity of both species composition and vertical structure. Single-tree or small group selection and irregular shelterwood systems will accommodate a wide variety of species covering a broad range of shade tolerances. Vertical stratification that results from differences in tree ages and species growth rates aids in filtering atmospheric pollutants and reducing the erosional impacts of precipitation. The methods chosen will balance the objective of maintaining vertical structure with that of maintaining the forest in a reproducing and actively growing state in order to shorten the recovery time following disturbance and to ensure stable regulation of water and nutrients.

Since the understory, midstory, and overstory overlap in any given forest area, it is difficult to gauge the balance of these components by measuring the area they occupy. A more efficient measure is to inventory an area's stocking by basal area and size, and to assume a correlation between the percent of the total basal area and the percent of the physical area occupied by a given tree size. The stocking guidelines shown in Table 10 are hypothetical examples influenced by storm exposures, site conditions, and species composition. For example, the objective on storm-exposed softwood sites is to increase the portion of the stocking in the smaller diameter classes, which generally correlate to lower heights.

Table 10: Stocking Examples for Intermediate and Exposed Sites

AGE CLASS	*SIZE CLASS*	*BASAL AREA DISTRIBUTION*	
I. HARDWOOD STANDS		INTERMEDIATE	EXPOSED
1-30 yrs.	1"-5" DBH	15 ft^2/acre	20 ft^2/acre
31-60 yrs.	6"-12"	35 "	40 "
61-90 yrs.	13"-19"	35 "	30 "
91+ yrs.	20"+	20 "	10 "
TOTAL BASAL AREA		100 ft^2	100 ft^2
II. SOFTWOOD/HARDWOOD STANDS			
1-30 yrs.	1"-5"	20 ft^2/acre	25 ft^2/acre
31-60 yrs.	6"-12"	45 "	50 "
61-90 yrs.	13"-19"	35 "	35 "
91+ yrs.	20"+	20 "	10 "
TOTAL BASAL AREA		120 ft^2	120 ft^2
III. SOFTWOOD STANDS			
1-30 yrs.	1"-5"	25 ft^2/acre	35 ft^2/acre
31-60 yrs.	6"-12"	55 "	65 "
61-90 yrs.	13"-19"	45 "	35 "
91+ yrs.	20"+	25 "	15 "
TOTAL BASAL AREA		150 ft^2	150 ft^2

Hardwood stands normally carry lower stocking compared to conifers. Furthermore, because hardwoods approach the critical hurricane damage height more slowly than softwoods, stocking percentages can be somewhat higher in larger diameter, older trees on all sites. Note that of the 14,850 acres designated to receive silvicultural attention this decade (see Supporting Appendices: Compartment Descriptions and Maps), 14,174 (96%) are located in areas that are physically "exposed" (70%) or "intermediate" (26%) according to the Harvard Forest hurricane model, so that shifting stocking percentages toward smaller, younger trees applies to the majority of the managed forest.

While regeneration cuts will occur, on average, every 20-30 years, slower growing hardwoods will be treated less frequently and faster growing softwoods will be treated more often. This is not intensive management by conventional forestry standards and will result in large amounts of unsalvaged mortality in all ages and sizes of trees, which in turn will result in the creation and retention of den and cavity trees, as well as the accumulation of widespread dead wood on the ground.

As tree reproduction becomes evident, silvicultural practices are planned across 1500-2000 acres per year, distributed among all five drainages (3-400 acres per drainage). Within this 1500-2000 acres, overstory removal to release established regeneration will occur on approximately 5-600 acres each year. Most overstory removals will be small, averaging 1/10 to 1/4 acre in size. Additional work will include limited intermediate cuts to maintain the vigor of groups of sapling and pole trees; single-tree selections, which encourage the development of advance regeneration; and larger group removals, when certain site conditions exist (see Release of Regeneration above for conditions). Figure 9 depicts the generalized, long-term silvicultural strategy for converting the current forest to one composed of balanced distributions of three age classes, which translate to three more or less distinct forest layers. The chart is predicated on the recovery of tree regeneration, and actual progress will vary with that recovery. Stocking measurements to quantify the impacts of silvicultural practices on age and size diversity will be conducted regularly. Figure 10 depicts ground-level views of the likely progression of the Quabbin forest through the year 2025.

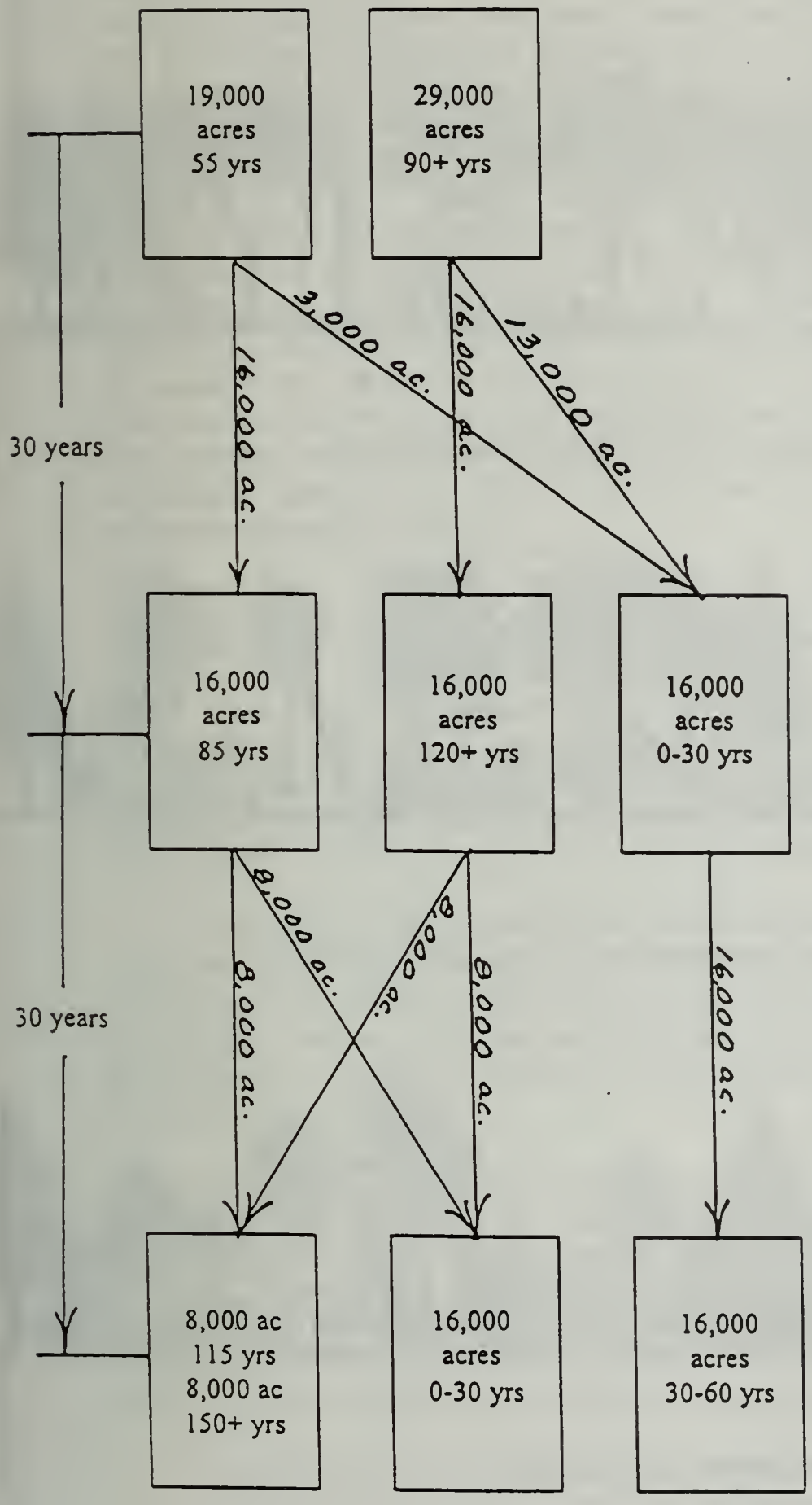
It is also important to note here that the goal of maintaining a continuous component of younger trees within the Quabbin forest will be accomplished by regenerating approximately two-thirds of the forest area, with approximately one percent of the forest area being regenerated each year on average. The remaining one third of the forest will continue to grow and mature during the next 60 years, unless it succumbs to natural disturbances. The Division has developed minimum standards for the presence of young forest throughout the watershed, but has no maximum standard for age or size of trees left to grow. Provided that management objectives remain constant, it is likely that there will always be individual and small stands of trees within the Quabbin forest that grow older, and larger, indefinitely.

4) Intermediate Cuttings

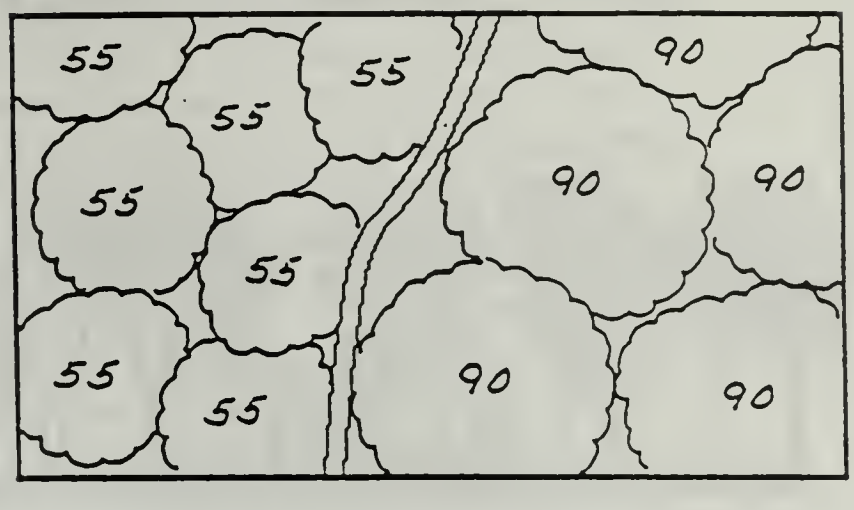
Intermediate cutting is the classic "thinning", which generally removes low-vigor trees in order to reduce competition within a dense stand of young or middle-aged trees, thereby enhancing the growing conditions of the remaining trees. While some regeneration often results from these intermediate cuts, it is incidental to the primary goals.

The objective of intermediate cuttings is to favorably impact existing stands. Intermediate thinnings uniformly remove trees in order to provide more space, light, water, and nutrients to the remaining trees. This activity normally improves the growth and vigor of the stand, thereby

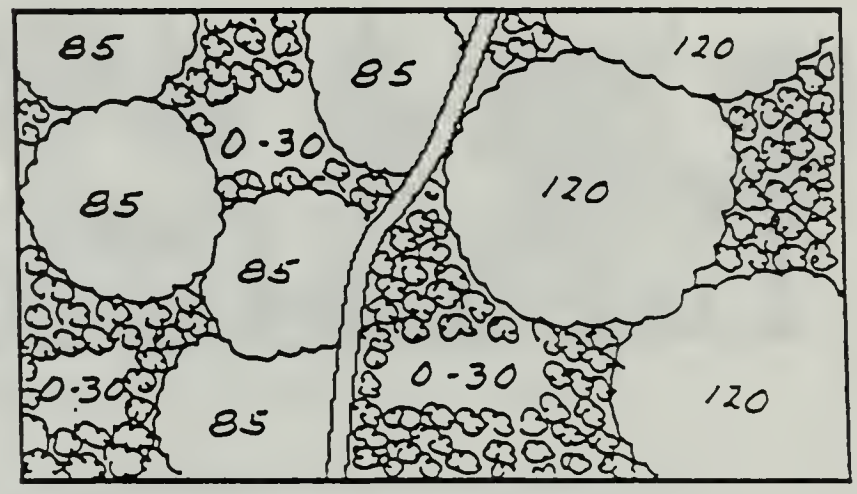
Figure 9: Quabbin Silviculture 1995-2055



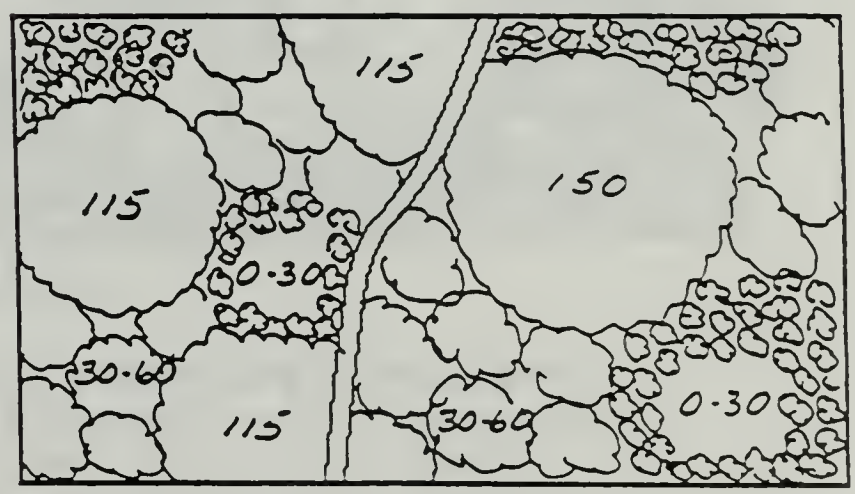
Structural Diversification of Representative Stand



1995



2025



2055

NOTE: each polygon in the above drawing represents a single tree crown of the specified age, viewed from above.

The double line down the center is a woods road.

Figure 10: Development of the Quabbin Watershed Forest Through Management

Present (1995) forest; high deer population, limited understory development

15 years from present (2010); following deer reduction and preparatory thinning

30 years from present (2025); following release of understory

Illustrations by Nancy Haver

improving its resistance to the various natural disruptions. There is an initial windthrow risk associated with thinning dense plantations, in part because thinning increases the "aerodynamic roughness" of the canopy. However, thinned stands emerge from a 5-10 year recovery period with larger individual root systems and greater average taper, which may improve wind-resistance beyond that of the original stagnant stand (Matthews 1989:30-36). A typical pine plantation thinning removes less vigorous, suppressed trees as well as poorly-formed dominant or double-topped trees (both of these have structural weaknesses in the face of wind). Basal areas in natural stands are reduced by 20-30% by these thinnings and by 30-50% in dense plantations.

In addition to improving individual vigor through density control, some thinnings are designed to improve stand composition. Trees that are not suited to the particular site, and are interfering with better-suited trees, are cut. An example would be a thinning in a mixed stand of pine and hardwoods growing on a site more suited to hardwoods. Pines on these sites are often structurally defective due to repeated weevil damage to their terminal buds, and are more easily damaged in storms as a result (Putz and Sharitz 1991). Removing these pines to favor the long-term growth and development of more resistant hardwoods supports the goal of a protection forest. Thinnings in hardwood types will be limited to approximately 400 acres over the next ten years, so that efforts can be focused on more important regeneration cuttings.

5) Plantation Management

There are currently approximately 2,250 acres of red and white pine plantations at Quabbin, as well as approximately 500 acres of planted spruce. Most of these plantations will be converted slowly to diverse mixes of native species. Red pine has successfully regenerated in some of the larger openings and will likely remain a component of the future forest. Spruce is an unusual species and wildlife habitat and will be retained, in a mix with other species, where it is appropriately sited.

Intermediate and/or regeneration cuts have occurred on approximately 690 acres of plantations during the 1990's. The Division's ability to work in these plantations has been enhanced by the availability of state-of-the-art harvesting equipment such as the feller-buncher with processing head and the log forwarder, which can work efficiently and with minimal damage in these dense stands. Improvements in markets for red pine have also enhanced the ability to accomplish silvicultural objectives in plantations.

In the 1991 Quabbin Reservation White-Tailed Deer Impact Management Plan, the Division proposed a 5-year moratorium on field creation through red pine plantation clearcutting. This decision was based on a desire to minimize potential food for deer during the initial deer reduction program. Given the values of forest cover that are detailed in Section III of this plan, no further field creations are planned for the next ten years. The one exception to this may be the creation of early-successional wildlife habitats in areas identified as suitable for "secondary uses" (see Section V.E. and V.C.4.). Section g. below describes the management of existing open areas.

Full overstory removals greater than one acre in size in plantations will be limited to those sites described in Section V.B.3.e. above, and limited overall to no more than 1% of the managed forest during this management period. A combination of preparatory and regeneration partial overstory cuts, along with an occasional sanitation cut to remove plantations infected with *Fomes annosus* root rot fungus, will continue into the foreseeable future in most plantations. The main

objective of silvicultural operations in plantations is to regenerate them to a mix of native species, in order to establish a more stable, low-maintenance, watershed protection forest.

The history of plantation management on Quabbin is summarized below:

Original Plantings.....6760 acres
Plantings That Survived.....3250
Partial cutting:
- 1960's.....730
- 1970's.....800
- 1980's.....900
- 1990-4.....790

Total Partial cutting.....3220 (some areas were thinned twice)

Clearcutting to create fields:
- 1970's.....100
- 1980's.....400
- 1990's.....none planned

Current Plantations.....2750

6) Management of Disturbance-Sheltered Sites

A computer model developed by Harvard Forest that predicts hurricane impacts to central New England forests was applied to MDC lands at Quabbin (Ottenheimer 1992). This model is based on the damage caused by the hurricane of 1938 to the Harvard Forest and makes damage predictions based upon slope orientation and angle, forest height and age, and forest type (Foster and Boose 1992). Approximately 91% of MDC lands was classified as intermediate or exposed, meaning that it would sustain large amounts of windthrow if a hurricane similar to that of 1938 struck the watershed. In Section V.B.2. of this Plan, a forest management alternative was selected that strives to diversify the forest, in part to reduce susceptibility to catastrophic hurricane damage. On sites that are clearly sheltered from catastrophic disturbances, management is less necessary than on exposed, susceptible sites.

General goals for diameter distributions have been formulated for exposed and intermediate sites (Table 10). However, on sheltered sites, management goals are simply to maintain the overstory and gradually establish diverse forest regeneration. Outlined below are some general procedures by which the Division will approach management of these sheltered areas.

Of the 4,800 acres classified as hurricane-sheltered, more than 1,600 are also classified as Areas with Special Management Restrictions due to special resources contained there or the difficulty of management of these lands. Of the remaining 3,200 acres, the Division plans to conduct light silvicultural operations on 700 acres over the next decade. These are areas where the Division has determined that understory establishment and overstory maintenance are of immediate concern. To the extent that the remaining 2500 acres are "sheltered" from major disturbances, they are generally a lower management priority than storm-susceptible sites. The Division will monitor these sites and evaluate the benefits of occasional forest management. Such management will be focused on sites that

do not develop diverse species composition, vertical structure, and forest regeneration through natural disturbances.

Section V.A.7.identifies Areas with Special Management Restrictions on which silviculture will not occur. However, a technical advisory committee will review, with the Division, the potential benefits of applying silviculture (harvest and non-harvest) to some of these lands in future management periods (especially steep slopes, islands, and riparian areas). The technical advisory committee will also assist the Division in evaluating the need for silviculture on lands that appear to be protected from major disturbances. (See also Section VII.C. for make-up of the committee and other policy issues for discussion).

7) Non-Harvest Silviculture on Sensitive Sites

There are areas across the watershed where adding new forest layers in order to improve disturbance resistance is a high priority but inaccessibility precludes commercial operations. On a limited area of less than 200 acres, small overstory openings will be created without removing forest products. The Division will select only those sensitive areas where there is a clear threat of loss of forest cover, with resulting effects on a tributary or shoreline area. Examples include shoreline pine plantations with restricted access, high hurricane exposure, and limited understory development (see Figure 11).

The technique would open the minimum amount of overstory required to allow understory development of either native regeneration or planted trees. Efforts would be made to fell trees across the slope, in order to strengthen the areas' buffering of overland flow, and to lop the branches to hasten decay, thereby reducing fire danger. This method has the advantage over natural disturbance of methodically selecting the timing, placement, and area of openings, which then fill with dense regeneration and "anchor" the area in the event of a major overstory disturbance. Since the trees will not be removed, there will be negligible risks of soil disturbance or erosion in these areas. As part of this pilot program, the Division will monitor the condition of understory vegetation before and after treatment.

8) Riparian Zone Management

A common riparian zone management strategy that land managers employ is simply to leave these areas alone. In fact, this strategy has the force of law in many states, as a component of wetlands protection or timber harvesting regulations. Mass. General Law, Chapter 131 § 40 (Wetlands Protection Act) and Chapter 132 (Forest Cutting Practices Act) both contain language that restricts activities within riparian zones. The assumption behind these regulations is that manipulations of these zones will degrade the critical buffering capacity of these areas and may result in soil disturbances that are more likely to result in sediment transport into streams. However, studies show that it is the activity of removing trees that is associated with these impacts.

Riparian zones are the final, and therefore most critical opportunity to slow or capture nutrients and sediments released by a variety of natural and man-caused events on the watersheds, before they reach the reservoir itself. Vegetation in these areas also has important value in maintaining stream temperatures. Although the study of processes by which riparian forests help

Figure 11: Areas of Non-Harvest Silviculture

MDC
Metropolitan Parks System
EST 1893

N

Non-harvest Silviculture
MDC Property
Non-MDC Property
Reservoir

All areas shown (approximately 200 acres of shoreline red pine plantations) are proposed for non-harvest silviculture for 1995-2004. Portions of these areas which cannot be treated commercially will be treated noncommercially, with the objective of enhancing understory development by reducing overstory density. Trees will be felled across the prevailing slope (to reduce erosion) and delimbed (to prevent fire hazard), but will remain on the forest floor. This treatment is only proposed for areas that border the reservoir, need understory development, and are not commercially treatable.

Map produced by Philip A. Lamothe, 1995.

protect water quality is an emerging field, researchers have noted the benefits of managed forest in riparian areas (U.S.D.A. 1991). Based on this research, the Division's preferred vegetative structure for riparian areas is an actively growing, diverse, self-perpetuating, and disturbance-resistant forest cover. Maintaining this forest structure in the face of disturbances that impact New England forests, including riparian zones, may be best accomplished through carefully planned and implemented human intervention. Some riparian forests are sheltered from wind damage simply by being located within the bottom of stream and river valleys. However, as these forests mature, and especially where they are in the path of prevailing storms, they become vulnerable to sudden and dramatic damage. Shoreline forests are especially vulnerable to wind damage. When damage occurs, it can result in substantial amounts of soil and nutrient transport, as well as sudden changes in stream temperatures, due to the loss of forest cover.

As is true for maintaining the watershed forest in general, the most important resistance to build into these forests is the establishment of regeneration. This regeneration serves to anchor soils following disturbances, resists damage from many disturbances (due to size and density), assimilates nutrients more rapidly than older vegetation, and shortens recovery times for reestablishing riparian forests following disturbances. Riparian forests that are simply left alone will establish regeneration as the overstory begins to age and decline in vigor. However, where full crown closure is maintained for long periods of time, understory development will be limited by low understory light and thus there will be delays in recovery following major disturbances. Through carefully implemented manipulations of the overstory and understory, Division managers intend to systematically "condition" certain vulnerable riparian forests to be better able to fulfill their critical buffering functions throughout disturbances. Three specific management strategies, and the types of riparian zones to which they will be applied are detailed below:

1. Standard silvicultural practices, including harvest removals of forest products, will occur in riparian areas within the managed forest, where soils and cutting practices allow (Section V.B.3.)

2. Directional felling of small groups and individual trees, without removal, will be done to bring light to the understory where soils or access problems prevent the use of harvesting equipment. Trees will be felled perpendicular to prevailing slopes and cut into sections so that the trunk comes in contact with the ground to enhance the sediment trapping capabilities of the riparian zone. Felling will not be done into streams (natural treefall adds sufficient material in streams to create beneficial debris dams).

3. Planting will occur in areas where seed source is limited or where herbaceous competition is a limiting factor. Planting with "tree tubes" sufficiently tall to bring seedlings above herbaceous cover may be used where herbaceous competition is intense. Some areas will be opened using non-harvest fellings prior to planting, in order to maintain light levels sufficient to support understory growth.

As 2. and 3. above are new approaches to riparian management at Quabbin, they will consist chiefly of directional fellings and tree plantings and be experimentally employed on no more than 200 acres in the next decade. The areas chosen for this treatment are ones where:

- an important buffer or riparian area is involved,

- the area is exposed to significant disturbance, such as from future hurricanes

- the area would benefit from planting and tubing to help establish regeneration in an expeditious manner.

One area selected, given these criteria, is the plantation on the east shoreline of the Prescott Peninsula in Compartment 4. This plantation is 18 acres in size, with approximately 2,500 feet of shoreline frontage, and very difficult access. The understory conditions of this plantation will be carefully documented before and after the proposed treatments, to test the effectiveness of this treatment. Other plantations with similar characteristics are also being considered (see Figure 11). Another example of riparian areas requiring attention are open, abandoned beaver meadows where tree regeneration is inadequate. Planting will be done in these areas, utilizing "tree tubes" where natural regeneration is delayed due to herbaceous competition.

9) Salvage Cutting

Because two thirds of the Quabbin forest is more than 80 years old, an increasing portion of silvicultural activities in recent years has been salvage cuttings, in response to natural disturbances. These activities are not planned, but are important components of watershed maintenance when the disturbance opens large areas. In these cases, removal of dead trees will lower fire hazard and may reduce nutrient inputs into the reservoir. Where large areas are involved, salvage activities may preempt planned activities listed in the sections above. When disturbance opens smaller areas, the Division's main concern is with reducing fire hazard (such as with hemlock looper or blowdown in pine plantations) or stopping the spread of certain diseases (such as *Fomes annosus* root rot in pine plantations). In cases where priority management is occurring adjacent to small disturbed areas, salvage is an efficient way of recovering some of the value of dead or dying trees and improving the chance of survival of remaining live trees, which have been stressed but not killed (for example, in areas of gypsy moth or oak leaf tier outbreaks).

10) Summary of Planned and Past Forest Management

To summarize the above sections describing the activities that are planned to meet forest management goals, the Division plans to complete the following silvicultural practices during the period from 1995-2004:

PRACTICE	ESTIMATED ACREAGE:
-Pine Plantation Intermediate and Regeneration Cuttings	1,185 acres
-Hardwood Intermediate Cuttings	423
-Native Forest Preparatory or Regeneration Cuts	13,325
-Areas of Non-Harvest Silviculture	200
-Tree planting	100,000 trees on 1,000 acres

By way of comparison, Table 11 summarizes annual silvicultural treatments since the 1960's. The decline in acres treated in recent years is due to changes in forest products markets (e.g., reduction in firewood demand), commitments made in the 1991 Deer Impact Management Plan, and the assignment of forestry staff to other projects including forest inventory, management plan preparation, boundary marking, and land acquisition.

Division foresters have prepared descriptions of the resources and past management of each of the 94 Quabbin management compartments. Silvicultural plans for the next ten years as well as GIS maps outlining existing resources and planned operations, are also included (see Supporting Appendices: Compartment Descriptions and Maps). Figures 9 and 10 above illustrate how this ten year plan fits into the long-term goals of forest management at Quabbin.

The progression of regeneration cuts in areas impacted by deer will be dependent on the ability of Quabbin's deer impact management program to achieve results. At present, deer population levels have been significantly lowered on 40,000 acres of MDC lands inside of the highways that surround Quabbin Reservoir, through controlled public hunting. In these areas, regeneration cuts to establish and/or release regeneration are proposed during the next ten years.

Table 11: Acres of Silvicultural Treatments, Fiscal Years 1960-1994

FISCAL YEAR	ACRES	FISCAL YEAR	ACRES
1960's (average)	900	1987	645
1970's (average)	950	1988	1,232
1980	2,202	1989	940
1981	1,037	1990	704
1982	1,831	1991	722
1983	1,598	1992	507
1984	1,369	1993	704
1985	1,512	1994	642
1986	1,169		

Preparatory cuts to establish regeneration will occur as needed on areas where deer control has begun but understory light is limiting. Cuts to release advance regeneration will occur primarily on the 8,500 acres of off-Reservation lands, where deer control has been active throughout MDC's control of the land, but will also occur inside the Reservation on areas where pine regeneration has become established on pine sites, despite moderate browse levels. Planting and non-commercial release cuttings may also be conducted on some of the 400 acres of land within Quabbin Park on which deer exclosures have been erected and successfully maintained.

The Division has adhered to a commitment made in the 1991 Deer Impact Management Plan to limit silvicultural activities for the period of 1991-5 to 4,000 acres (average 800 acres per year).

For the period of 1996-2004, the Division will accelerate the silvicultural treatments that prepare for and encourage regeneration in areas where deer management has been successful.

In implementing and monitoring this ten year plan, the Division will utilize the Geographical Information System (GIS) presently in use by the agency. This system has already been useful, for instance in comparing hurricane exposure areas to those areas where silviculture is planned (of the 14,850 acres where silviculture is planned, 70% is in hurricane exposed areas, 25% is in intermediate areas, and 4% is in areas sheltered from hurricanes, (Figure 7)). GIS will be utilized to assess each year's silvicultural treatments with regard to the goals of this plan, as they are refined and updated at each annual planning workshop (see Section VII.B.).

The Division recently instituted an expanded forest examination system to be utilized prior to and following the implementation of silviculture on the watershed. More detailed stocking and regeneration measurements will be taken so that specific goals for regeneration removals can be generated in order to implement the management program as accurately as possible.

Management activities in the past have been organized within large areas referred to as "Blocks", each of which was further divided into convenient management "Compartments". The condition of each of the 94 Compartments in the five Blocks (Pelham, Prescott, New Salem, Petersham, Hardwick) is described, and planned silviculture for the compartment is mapped and described in Supporting Appendices: Compartment Descriptions and Maps. As the Division moves to implement cumulative sub-basin analysis (in order to set management priorities more directly to hydrologic sub-units of the watershed) "Blocks" will be replaced by major drainage regions. The table below shows past and proposed new divisions for these major areas. This conversion will help improve coordination between watershed protection priorities and forest management priorities.

Past "Block"	Area Included	Proposed New Designation	Area Included
Hardwick	MDC land in Towns of Hardwick, Ware, including Quabbin Park	Eastern Drainages	Quabbin Park, plus lands draining the Eastern slopes of the watershed
Pelham	MDC land in Belchertown, Pelham, and portions of Shutesbury	Western Drainages	Lands draining the Western slopes of the watershed
New Salem	MDC land in New Salem (excluding Prescott Peninsula), parts of Shutesbury, Wendell, Orange	Swift River Drainage - West Branch	Lands primarily drained by the Middle and West Branches of the Swift River
Prescott	Prescott Peninsula	Prescott Peninsula	Prescott Peninsula
Petersham	MDC land primarily in Petersham	Swift River Drainage - East Branch	Lands drained by the East Branch of the Swift River and by the East and West Branches of Fever Brook

f. Silviculture by Forest Type

The principal forest types on Quabbin are described below, with a brief description of silvicultural approaches applicable to each type within the context of watershed management. These types may occur as pure stands, or more often as mixed forest with either gradual or sharp changes related to soil types, aspect and elevation, and past land use history. The Compartment Descriptions and Maps in the Supporting Appendices describe the location and extent of these types in more detail, with particular reference to stands unusual for their species composition or growth characteristics.

1) Oak Type

Red, black, scarlet, white, and chestnut oak comprise the five major species in this type, with red oak generally the most vigorous, dominant component. The type grows best on the more fertile, moist, moderately well-drained sites. Because of its superior vigor, red oak will be favored where moisture is sufficient to support its growth. While Quabbin is host to some of the largest contiguous oak stands in the Northeast, it is important to recognize that these stands were established through dramatic clear-cutting and burning. Regenerating red oak through more conventional silviculture has been difficult, especially in the presence of high deer populations. It is likely, therefore, that the uneven-aged silviculture proposed by this plan will ultimately result in the replacement of these oak stands with a wider diversity of species. While this replacement may compromise other values of these contiguous stands, such as hard mast (acorn) production, it supports the Division goal of increasing species diversity to improve stand resilience.

Scarlet and black oaks are plentiful on some well-drained upland sites (where lack of moisture limits red oak) but are generally of poor vigor. Gypsy moth infestations in the past have been most severe on these drier sites. Consequently, efforts have been made to increase the component of other species on these uplands, e.g. by salvaging dying oaks and underplanting with white pine in the resulting openings. White pine survives and grows well on these sites and the majority of these black and scarlet oak stands will eventually be converted to mixed stands of oak and pine.

White oak, like black and scarlet oak, is also found growing on dry upland sites. However, it exhibits its best growth on moister soils. The fruit of the white oak is less acidic than the other, more abundant oak species, and consequently more valuable to wildlife. On the Quabbin watershed, white oak was a primary host to the gypsy moth and, due to physiological differences, suffered more severe mortality than the red oaks. White oak that is surviving and growing vigorously will receive preferential treatment in order to maintain the species as a component on the watershed.

Chestnut oak is primarily found growing on the poorest of upland sites on southern and eastern exposures in shallow soils, especially inside of Route 202. North of Route 202 in the West Branch of the Swift River, chestnut oak was commonly found growing with red and white oak. However, gypsy moth infestations of the early 1980's eliminated nearly all of the chestnut oaks from these stands. Regeneration of chestnut oak has been successful where deer have been hunted. Because this species occurs in relatively few sections of the watershed, it is desirable to maintain it as the major component of a mixed stand as opposed to aggressively converting the stand to white pine.

2) White Pine Type

White pine is among the fastest growing species in the region and responds well to management. It is found most often on dry, sandy sites where hardwoods do not grow well or in

abandoned pastures and fields where its heavier seed is capable of penetrating thick grasses more successfully than hardwood seed (Spurr and Barnes 1980:444). White pine grows most vigorously on moist sandy and silty loams, but it is difficult to establish on these sites because of hardwood competition. Where deer browsing levels have been moderate, there are moist sites where white pine has become established on moist sites due to preferential browsing on hardwoods. These areas will eventually support a more mixed composition, but will tend toward white pine for the next generation.

Most of Quabbin's white pine stands are 55 to 90 years old, the result of natural seeding in old, abandoned pastures and fields, vestiges of stands damaged during the 1938 hurricane, and remnants left over from silvicultural operations prior to MDC ownership. White pine that becomes established in low densities in abandoned pastures is often exposed to repeated white pine weevil infestation. The resulting multiple leader crown is often more susceptible to wind and ice damage and subsequent fungal invasion. Where these occur as isolated trees, they do not constitute a risk to watershed cover maintenance. However, where they comprise the majority of a stand, their gradual removal and replacement with understory trees that will develop a stronger form is desirable.

Some of the Quabbin white pine component is within plantations established in the 1930's and 1940's. Many of these plantations were planted as a mix of red and white pine. The sites chosen were often moist, rich agricultural sites, where red pine grew much more vigorously than white pine. In addition, these moist sites correlate with high infestations of the white pine weevil. As a result, much of the white pine that has survived in plantations is suppressed beneath the red pine, and shows signs of repeated weeviling. Intermediate cuts in these mixed plantations will continue to preferentially remove the white pine. For more detail on white pine in plantations, see Section V.B.3.e.).

3) Red Pine Type

Red pine is an uncommon species in this area, but was successfully established, in conjunction with planted white pine, on approximately 2,750 acres on the Quabbin watershed during the 1930's and 1940's. Red pine is capable of growing well on a variety of sites, but is most stable on moderately well-drained, sandy loams, where root depth is less limited. On the more moist and fertile sites, red pine has grown to a total height of 90 feet and a diameter at breast height in excess of 24" within 50 years from planting. However, it is on these same sites that red pine has exhibited susceptibility to root rot diseases and to wind throw. For watershed purposes, it is desirable to convert these sites to a more reliably stable cover of mixed native hardwoods. This conversion will occur gradually, with an initial thinning in dense, previously unthinned stands, followed by regeneration cuts to establish the native hardwood understory. Where root rot diseases have killed more than scattered trees, sanitation clearings will be conducted both to halt the spread of the disease (which passes from tree to tree through root grafting) and to hasten the conversion to site-suited species.

Red pine planted on drier sites will be managed through initial preparatory cuts to establish regeneration, followed by regeneration cuts to release new forest layers. Where light is sufficient, red pine has successfully regenerated, most notably in larger openings created for water yield in the 1980's. It is likely that red pine will remain as a component of mixed, naturally regenerated stands on limited areas of the watershed forest (see Section V.B.3.e. for more detail on red pine management).

4) Birch/Red Maple Type

Black and paper birch, as well as red maple, will occur as pioneer species on many sites, but this overstory type is generally found growing only on moist sites, where red maple is usually the dominant species. While it tolerates these sites better than most species in the establishment phase, maturing red maple is quite susceptible to heart rot where soil drainage is slow. Generally, the black and white birches that establish successfully in these areas do not thrive beyond about forty years of age. Black or sweet birch is particularly susceptible to *Nectria* canker and paper birch in these areas may develop red heart, a fungal complex. Both the stems and branches of the birches are damaged easily by ice and heavy snows.

In some cases, birches dominate the overstory because they were a less preferred deer browse in early stages of succession, or were able to outgrow livestock grazing on pasture sites. The same browsing/grazing pressure apparently prevented later successional stage components, such as oaks, ashes, sugar maple, and hemlock, from replacing the pioneers. Where there are scattered stems or small groups of more long-lived species, intermediate cuts will favor their growth and development as seed sources. Regeneration cuts will then reestablish stand development after browsing pressure has been reduced.

5) Hemlock Type

Hemlock grows most often in cool moist areas along brooks and streams and on north-facing slopes, but is also found on a wide variety of other sites. Hemlock stands are generally the best winter deer cover on the watershed and have been heavily browsed. As a result, hemlock regeneration has been extremely limited across the Quabbin Reservation. Hemlock is quite susceptible to gypsy moth infestation, especially where it occurs as scattered trees within oak stands. The hemlock looper has caused rapid mortality in hemlock stands throughout the northeast portion of the Quabbin forest in recent years.

Due to these pressures on the species, the majority of silviculture within the type during this decade will be salvage operations and scattered light thinnings to maintain vigor and seed-producing capabilities. However, where diversification of vertical structure within hemlock stands is desirable, regeneration cuts will be conducted.

6) Spruce Type

The majority of the spruce trees growing at Quabbin were planted in the late 1930's and early 1940's. Norway, red, and white spruce were planted. While some of the Norway spruce plantations have grown very well (in particular, on Prescott Peninsula), the red and white spruce generally did poorly. Approximately 500 acres of spruce plantations survived establishment. Only limited silviculture has been conducted in these stands, due to poor markets and the difficulty of felling and processing the limby stems. Currently, markets have improved and new equipment has increased the workability of these stands. These improved opportunities will be utilized to create additional forest layers as needed in these uniform stands. Spruce regeneration has been most successful in more open conditions and efforts will be made to gradually enlarge existing openings and create new openings to perpetuate this unusual component of the forest.

There is evidence in the literature that some of the spruces are among the best choices of species for wind tolerance. Spruce wood is generally quite strong relative to other conifers, and its

stem tapers very slowly, increasing resistance to breakage. Spruces cones are well-utilized by a variety of wildlife. Black spruce is also particularly tolerant of wet conditions and an appropriate plant for revegetating deforested riparian areas. For all the above reasons, spruce will be among the species considered for planting in wetter riparian areas.

7) Northern Hardwoods

Northern Hardwoods include sugar maple, black and yellow birch, beech, and white ash growing on fertile sites on thick, moist, moderately well-drained, fine, sandy loams. Although they have survived insect attacks, dieback, acid deposition, and increased ozone concentrations, the perpetuation of these stands has been most heavily influenced by wildlife impacts. Seeds that manage to escape animal consumption and germinate into seedlings, with the exception of black birch and beech, have been browsed by deer on much of the Reservation. Because this type often grows in the moist bottomlands, mature trees are often girdled or felled by beaver, especially where deer browsing has eliminated other food sources. While there are a few pure stands of these species, they are usually found scattered throughout other types and will receive preferential treatment over most other species, due to their rare occurrence.

g. Open Lands Management

This plan has repeatedly justified the maintenance of forest cover on the vast majority of MDC's watershed lands. In fact, it is the Division's intent to work with private landowners on these watersheds toward the same goal. However, approximately 3,955 acres (7% of MDC Quabbin lands) are currently in an open condition, including 2,270 in open wetlands (chiefly beaver flowages), 175 acres of utility rights-of-way, 690 acres in access roads, and 320 acres of open land in Quabbin Park. During the 1980's approximately 400 acres of fields were created by the Division by clearing pine plantations, primarily to increase water yields. An additional 100 acres of plantations were opened by small windthrow events.

In some of the above cases, there is a clear need to maintain the open area. For instance, rights-of-way will remain open indefinitely, in a combination of young trees and herbaceous species. Similarly, the majority of the road system on Division lands is maintained to provide access for policing, water sampling, silvicultural operations, and fire protection, as well as for recreational and research access. These 690 acres are unlikely to diminish.

The future of the remaining 2,990 open acres is being considered on several fronts. In all cases, the options include:

- to continue to maintain these areas as open land;
- to allow them to regenerate to forest on their own;
- to plant them to trees in order to accelerate their return to forest.

The new management plan being developed for the Quabbin Park (see Section V.F. for outline), will reconsider the value of maintaining mowed fields on the Reservoirs edge, or on any area that is critical to water quality protection. The open fields created in the recent past by clearing pine plantations will be subjected to an analysis of their importance to water quality protection. Those that are in areas of critical importance will either be allowed to regenerate to forest on their own, or will be reforested through planting.

Areas that are less important to water quality protection will be maintained through mowing or prescribed fire, in order to maintain their value for wildlife, historical preservation, aesthetics, and moderate water yield increases. Areas that are open and are not on drinking water supply watersheds will be maintained for the above reasons as well (the MDC currently owns more than 4,400 acres of land that is adjacent to, but not actually on, the Quabbin watershed - see the following section for plans on these lands). The creation of additional open areas to meet the above objectives, on lands that are not critical to water quality protection, or that are off the watershed, will be considered pending the completion of the "cumulative sub-basin analysis" project (see Section V.E.).

The largest proportion of the current open land is non-forested wetlands, primarily those created by beaver clearing and flooding and maintained in herbaceous cover by heavy deer browsing. Each of these areas will be considered carefully to determine the need for management. The water quality protection analysis is somewhat more complex for these areas than it is for non-wet openings. Beaver meadows high above the reservoir, on relatively flat terrain and with stable dams relate to long-term water quality protection quite differently than those near the reservoir on steep streams and with questionable dam stability. The impact of deer browsing on the cover that occupies these open beaver wetlands has clearly been to increase herbaceous cover at the expense of young tree cover. With deer control, beaver flowages should begin to revert to young tree cover, which will improve their condition with regard to watershed protection.

h. Management of MDC-owned Off-watershed Lands

The MDC owns approximately 4,400 acres of land immediately adjacent to, but not actually on the Quabbin watershed. The Division is in the process of developing separate management criteria for these lands, since their function is different than land that is on the watershed. Listed below are some of the concerns and proposals being considered:

- The Division should determine which of these lands are on critical areas of other drinking water supply watersheds (e.g. lands in the western drainages that are on Springfield's water supply), and meet with these other water supply agencies to discuss appropriate management.

- Lands that do not have direct bearing on drinking water supplies should be considered for "secondary uses", as described in the section below on "cumulative sub-basin analysis" (Section V.E.). These could include education and research, natural areas, wildlife habitat management, or timber management.

- For the sake of discussion, the Division should inventory these lands sufficiently to be able to write a management plan that demonstrates the revenue-generation potential of the forests they contain. This potential should also be discussed with the Massachusetts Water Resources Authority, which funds Division operations.

- In many cases, these lands serve as a buffer to potential impacts from public access (especially where the reservoir shoreline is near the watershed boundary) or forest fires. These values should be taken into account when planning management of these lands.

4. Best Management Practices for Watershed Forest Management

Forest management on Quabbin is done to improve watershed protection. As a minimum Best Management Practice, the Division will uphold the standard that no measurable negative impact on the quality of water, as measured at locations downstream from a logging project, will occur. Division staff will measure water quality periodically upstream and downstream from logging projects to assure compliance with this standard. Described below are the specific practices designed to accomplish this compliance. It should be noted that the Division meets or exceeds the requirements of both the Forest Cutting Practices Act and the Wetlands Protection Act (M.G.L. Chapters 132 and 131). As this Plan is going to publication, the regulations for these two laws are under revision. Most aspects of these revisions have already been incorporated below. Whenever these regulations are revised, Divisions management practices will meet or exceed the revised standards.

a. Introduction

Strict adherence to MDC's Best Management Practices (BMP's) ensures that forest management is conducted in a manner that does not impair water resources or other natural/cultural resources on the watersheds. Silvicultural practices, as described in the management plan, are employed to bring about specific forest conditions. These practices require the cutting and removal of overstory trees to diversify structural and species compositions and to maintain the vigor of the residual overstory. The forest is treated, on an average, every 25-30 years and at that time, up to 1/3 of a stand may be removed to establish and release forest regeneration. The process of removing trees can impact the forest and soils essential to water quality.

Among the areas of greatest concern are the placement of forwarder and skid roads and log landings, where logging work is concentrated. Proper location of these in relation to streams, rivers, reservoir, ponds, vernal pools, and bordering vegetated wetlands is important so that soils do not move from these areas into water or wetland resources. Beyond this principal concern, Best Management Practices are designed to diminish the negative impact of silvicultural operations on the residual vegetation, to minimize soil compaction during these operations, and to keep potential pollutants out of the water resource.

b. Variables

There are many variables to consider when planning and conducting a logging operation, including equipment limitations, weather, soil depth, soil moisture, topography, silvicultural practices, vegetation, and operator workmanship. Variables such as weather, soil moisture, soil depth, topography, and existing vegetation are beyond human control. The constraints they place on logging must be accepted, and logging schedules and expectations adjusted accordingly. Variables such as equipment, silvicultural planning, and operator workmanship can be modified, for instance by matching allowable logging equipment with the constraints of a given site.

c. Logging Equipment and Systems

In the 30 years that forest management has been active on MDC watersheds, logging equipment has changed dramatically. The primary logging machine was once the 50-70 horsepower (hp) crawler tractor-sled combination. These tracked machines were 5-6' wide and weighed 5-7 tons. Today, most logging is done with a 4-wheel drive articulated skidders or forwarders with 70-100 hp, widths of 7-8', and weights of 6-8 tons. Skidders drag logs attached to a rear-mounted cable and winch, while forwarders carry logs on an integrated trailer.

Other types of logging equipment include grapple skidders, wheeled and tracked feller-bunchers, and feller-processors. A grapple is an add-on feature that replaces the winch and cable with hydraulically operated grapple arms. Feller-bunchers cut trees and put them in piles, usually for removal by a grapple skidder. There are 3 or 4 wheel feller-bunchers that must drive up to each tree for felling, whereas tracked models can fell a tree 10-20 feet from the machine. A feller-processor (usually on tracks) fells, de-limbs, and cuts trees, leaving piles of logs or cordwood, which are retrieved by forwarders.

Small skidders are useful for logging on watersheds whereas larger 100-130 hp models, that weigh between 8-11 tons and are 8-9' wide, are usually too large and heavy for stand and soil conditions. Combinations of small, maneuverable feller-bunchers and forwarders, small skidders and forwarders, and small tracked feller-processors and forwarders have all worked successfully on MDC watersheds. Table 12 shows typical combinations of equipment that work on various types of harvesting operations on MDC watersheds.

Table 12. Harvesting methods/equipment used on MDC watershed lands, listed by most frequently harvested products.

Method/Equipment	4-8' Cordwood or pulpwood	8-20' Sawlogs, fuelwood, pulpwood	Whole-tree
1. Chainsaw felling with 4wd pickup truck	✓		
2. Chainsaw felling with cable skidding	✓	✓	
3. Chainsaw felling with forwarding	✓	✓	
4. Rubber-tired, four-wheeled feller/buncher with grapple skidding		✓	✓
5. Rubber-tired, four-wheeled feller/buncher with chainsaw limbing and forwarding		✓	✓
6. Rubber-tired, three-wheeled feller/buncher with grapple skidding			✓
7. Tracked feller/buncher with grapple skidding		✓	✓
8. Tracked feller/processor with forwarding	✓	✓	

In an effort to specify equipment that is appropriate on specific soils and within specific forest types, the Division has determined ground pressure and width measurements for most of the equipment common to the area, and specifies restrictions, where needed, in timber harvesting contracts. Widths are either from direct measurement or from manufacturer's specifications; ground pressures are based upon a formula that combines machine weight and weight of an average load of logs with an estimated footprint for the tire size specified, at an average tire inflation pressure. Examples from this rating system are listed in Table 13.

Table 13. Sample equipment size/ground pressure ratings

Machine Model	Tires	Width	Ground Pressure
TimberJack 208	23.1x26	102"	4.9lbs/sq in
JohnDeere 440C	23.1x26	102	5.0 "
Franklin 105XL	23.1x26	110	5.3 "
TreeFarmer C4	18.4x26	93	6.5 "
JohnDeere 540	23.1x26	105	6.6 "
CAT 508GR	23.1x26	110	7.1 "
Clark 665	23.1x26	110	7.9 "
Clark 665	18.4x24	104	9.5 "
TreeFarmer C6	18.4x34	97	10.1 "
CAT 518	18.4x34	99	11.2 "

Some of the logging equipment available is too large or heavy to meet MDC requirements in certain vegetation or soil conditions, and some is limited by terrain. Matching the equipment with the site conditions so that minimal damage occurs is critical to the success of watershed silvicultural activities. MDC specifies equipment requirements for each site in its contract bidding. This includes machine width and ground pressure limits, as well as specific equipment requirements (e.g. forwarders, etc.). While each site has unique conditions that require the experienced judgement of the forester to predict impacts, ground pressures are generally limited to 8 pounds per square inch or less on soils that are less well-drained (Types 4 and 5 - see Section II.B.1.), and machine widths are limited in intermediate cuttings of dense, unthinned stands with moderate topography, most typically to around 8.5 feet (102").

An example of a "preferred logging system", that accomplishes MDC goals under difficult conditions, is a small feller-processor and forwarder combination, used for thinning dense pine plantations on a variety of soil conditions. Both machines are able to work in these conditions with minimal root, stem, crown, or soil damage. In addition, these machines can successfully work around walls and foundations and do not require a landing, as logs are stacked on the roadside. This combination can also work in previously thinned stands that have an understory of young pines, with minimal damage to the young growth.

The feller-processor is limited to stable ground conditions (few rocks and gentle slopes) and trees less than 16" DBH. In older multi-aged stands where the trees are much larger, hand felling is necessary. Multi-aged stands will always have many more stems/acre than the present even-aged stands and consequently are more difficult to work in without damaging residual trees. A combination of a winching machine and forwarder works well in multi-aged stands. This logging system addresses the problem of damage to the residual trees associated with long skid roads.

Table 14 summarizes some of the Division's effort to match equipment and logging systems with site conditions. The methods listed in Table 14 are taken from Table 12.

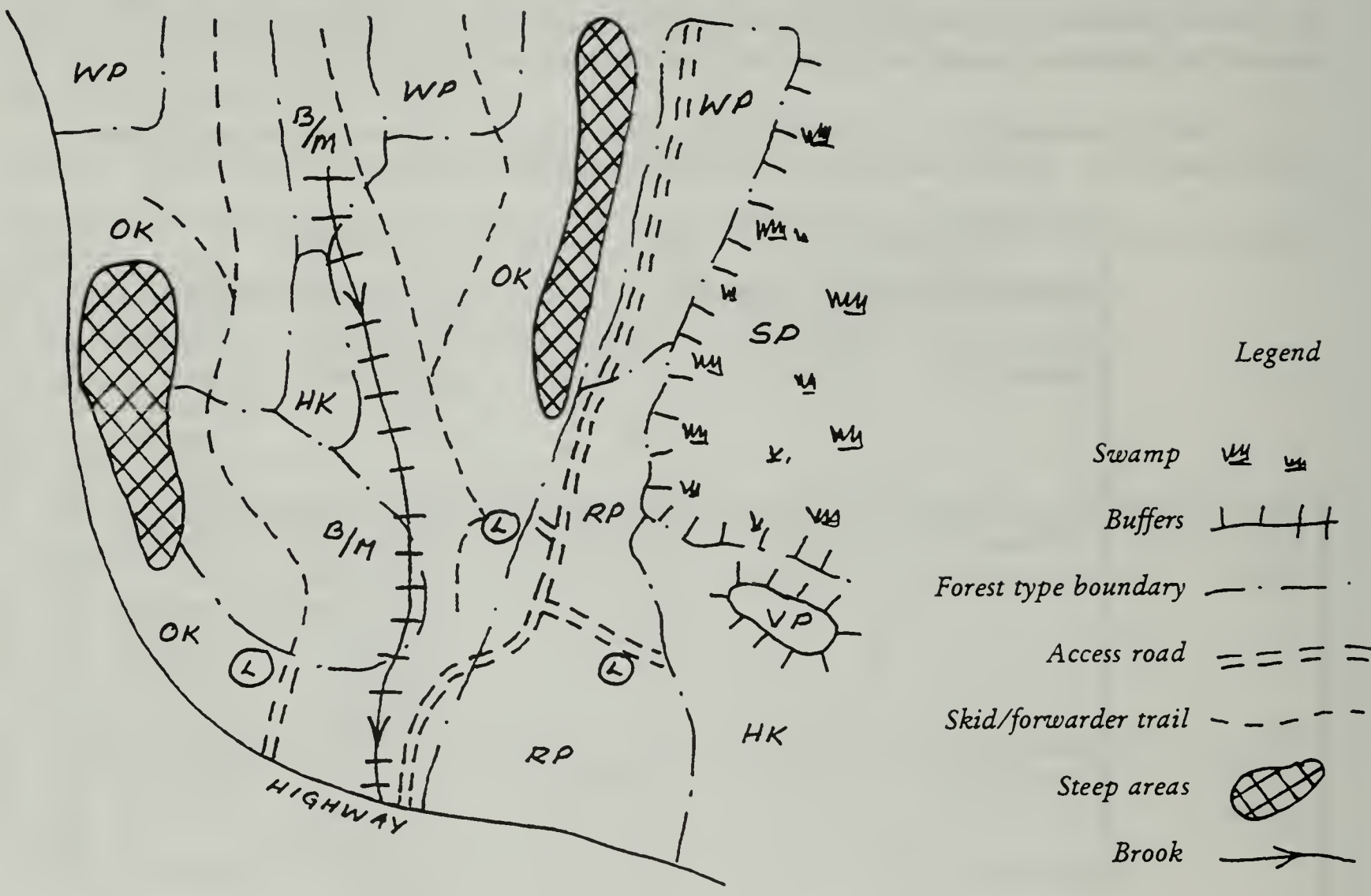
Table 14. Harvesting methods/equipment used in various soil/terrain combinations.

	Excessively drained soils	Well-drained thin soils	Well-drained thick soils	Moderately well-drained soils	Poorly to very poorly drained soils
Level to 10% grade	Methods 1-8	Methods 1-8	Methods 1-8	Methods 1-8 with frozen or dry soils only; ground pressure < 8 lbs/sq in	Generally not worked with machines
11-20% grades	Methods 2-6	Methods 2-6	Methods 2-6	Methods 2-6 with frozen or dry soils only; ground pressure < 8 lbs/sq in	NA
Slopes greater than 20%	Method 2	Method 2	Method 2	NA	NA

d. Silvicultural Planning

Silvicultural plans have to address present and future cutting practices, landscape aesthetics, cultural resources, wildlife resources, wetlands, and rare or endangered species. While the protection of non-tree resources is of particular concern, the most difficult aspect of planning concerns the maintenance of multi-age stands of trees. These stands have great numbers of trees, especially seedlings, saplings, and poles that are more easily damaged than larger trees. The positioning of permanent logging roads, landings, and small and large group cuts is crucial to the long term success of silviculture. Logging operation success is dependent upon careful advance planning (see Figure 12 for an example of silvicultural planning).

Figure 12. - Hypothetical Example of Silvicultural Planning



This approximately 200 acre area of the Quabbin forest contains separate stands of white pine (WP), hemlock (HK), birch/maple (B/M), oak (OK), spruce (SP), and planted red pine (RP). A fire in 1957 severely burned the lower 1/3 of the area, and the red pine was planted shortly after this fire. This area has been legally hunted for deer throughout MDC's control.

The topography and hydrography of the area include large areas of well-drained, sandy soils, but also several small steep areas, a year-round brook, a swamp, and a vernal pool (VP). These areas are delineated with buffers, where required. Work within these areas is restricted; steep areas and muck soils are not worked, and buffers are only worked on frozen or dry ground. Fairy shrimp and mole salamander eggs have been found in the vernal pool, verifying its importance to wildlife. No work is proposed adjacent to this pool.

Except for the steep and wet areas, all the stands have received preparatory cuttings within the past 25 years, and the understory has developed in response. Additional work in this area will develop the midstory, using individual tree and small group selection methods of regeneration release. White pine, hemlock, and mixed hardwood enrichment planting is planned for areas where understory species diversity is limited.

Primary access is across the permanent road shown by a double dashed line. Single dashed lines are skidder and forwarder roads which have been used in the past and seeded and drained to prevent erosion. Landings are designated by a circled L, and also represent areas used in the past and maintained as wildlife openings between operations. These roads and landings will be used again in current operations, and then returned to grass. There is evidence that the landings, in particular, have been used between operations by wild turkey.

e. Operator Workmanship

Operator workmanship is one of the most crucial and variable factors in forestry operations because good planning and preparation can be negated if operators perform poorly. Most loggers are paid on a piece-work basis. Their paycheck does not always relate to how hard or how carefully they worked, but on the amount of wood that gets to the mill. However, the Division maintains tight control over loggers working on the watersheds, and exercises its right to remove operators who fail to adhere to contract standards. It is important that foresters and loggers develop mutual respect that is based upon a shared commitment to the sustainable stewardship of the land.

f. Filter Strips

Filter strips are vegetated borders along streams, rivers, or water bodies (including vernal pools) and represent the final opportunity to prevent transport of sediment or nutrients into streams or reservoirs from nearby roads or landings. When roads and landings are near water resources, filter strips are given special attention. Chapter 132 (Forest Cutting Practices regulations) requires a 50 foot filter strip, in which cutting is limited to 50% of the basal area and machinery is generally not allowed (exceptions include stream crossings).

Chapter 132 regulations require increasing the filter strip, dependent upon slope conditions, and along Outstanding Resource Waters (protected public water supplies) and their tributaries (excluding Vernal Pools and bordering vegetated wetlands), streams that are 25 feet or more from bank to bank, ponds of 10 acres or greater, and designated scenic rivers. The Division meets these requirements and also increases the filter strip, based on both slopes and soils, for other areas not included in the definitions above. For example, on moderately and poorly drained soils the filter strip is increased 40 feet for each 10% increment of slope angle above 10%. On well-drained outwash and till soils the filter strip is increased 40 feet for each 10% increase in slope angle above 20%. Equipment may enter the filter strip in limited cases where streams must be crossed (see Section V.B.4.i.4). below).

In Section V.B.3.e., the Division has outlined a pilot program to perform non-harvest silviculture in certain riparian areas in order to increase structural diversity and watershed protection. In this program trees may be cut within the filter strip, in order to stimulate new or existing regeneration and thereby increase the disturbance resistance of the riparian zone. This young growth is also desirable where it will improve the nutrient assimilation rate of these riparian areas. These operations will not remove wood products, will cut less than 50% of the basal area and will fell trees across slopes to maximize erosion barriers.

g. Buffer Strips

Buffer strips are retained and managed for aesthetic purposes along the edges of highways and public roads. Chapter 132 requires that within this strip, no more than 50% of the basal area be cut at any one time and that no additional trees be cut for five years. Buffer strips will be 50 feet except along designated scenic roads, where Chapter 132 requires them to be 100 feet in width.

h. Wetlands

The Division's forest management operations will comply with all the requirements of the Wetlands Protection Act, M.G.L. Ch. 131 § 40, and the Forest Cutting Practices Act M.G.L. Ch. 132 § 40-50 for cutting in wetlands (including bordering vegetated wetlands and freshwater wetlands as defined in the most current revision of Chapter 131 and 310 CMR 10.00 and as these are revised from time to time). Generally, activities that are not conducted under a Chapter 132 Forest Cutting Plan but will alter wetland resource areas (which include a 100 foot "buffer zone" beyond the water or the bordering vegetated wetland), are subject to approval through the filing of a Notice of Intent with the local conservation commission.

All of the Division's silvicultural activities that involve wetland resources are conducted under a Chapter 132 cutting plan, and therefore are exempt from Chapter 131 procedures, with the exception of limited amounts of work that does not include harvesting, including planting, pruning, and pre-commercial thinning and maintenance of boundaries and fire breaks. All of these latter activities are defined as "normal maintenance of land in agricultural use" by Chapter 131, and are therefore exempt from its filing procedures.

Chapter 132 requires a 50 foot filter strip along all water bodies and Certified Vernal Pools (see section f. above and i. 4). below), but allows harvesting in wetland areas provided that no more than 50% of the basal area is cut and the ground is only traveled by machinery when it will support that machinery (when it is frozen or dry). In addition, the Division does not allow machinery within low, flat wetland forest with deep muck soils that are seasonally flooded, even though statewide regulations allow work in some of these areas during frozen or dry conditions. Of the 4,500 acres of poorly or very poorly drained, Type 5 (see Section II.B.1.) soils, the Division estimates there are fewer than 1,000 acres of true "muck" soils on the watershed, most of which are included within the designated wetlands on the watershed. The Division has identified and mapped approximately 2,300 acres of wetlands within the Quabbin property, which are avoided when lot boundaries are drawn for proposed annual silvicultural operations. The Division also adheres to the statewide recommended practices for protection of vernal pools, including a 50 foot shade zone and a 200 foot buffer (see Figure 13).

i. Logging Practices

A primary purpose of BMP's is to prevent or minimize the movement of soil to the water resource. During a logging operation, this is most likely to occur on a landing or skid/forwarder road. In these areas, the humus layer is sometimes lost and the soils may be temporarily compacted and channelized so that water will flow over the surface instead of passing through the soil. If the road is unwisely placed on a continuous slope, rain water will increase in volume and velocity as it travels down-slope, scouring the path, removing soil, and creating a gully. If the road connects with a stream, the suspended soil may be carried much further. The result of careless logging practices can be erosion, increased stream turbidity levels, and deposition of the eroded materials downstream.

Logging practices and the human behavior necessary to avoid environmental degradation during logging are discussed in the following sections. A cutting plan still relies upon the judgement and common sense of the logger and forester to make the right decisions in order to protect the land and associated resources.

Figure 13. *Timber Harvesting Guidelines Near Vernal Pools*

Adapted for the 1992 NESAF meeting from guidelines which were cooperatively developed by foresters and wildlife biologists in Massachusetts.

Vernal pools provide critical habitat for a number of amphibians and invertebrates, some of which breed only in these unique ecosystems, and/or may be rare, threatened or endangered species. Although vernal pools may only hold water for a period in the spring, the most important protective measure is learning to recognize these pool locations, even in the dry season. Foresters can then incorporate the guidelines below into their plans to ensure that these habitats thrive.

Vernal Pool and Depression — *No activity*

Objective 1: Maintain the physical integrity of the pool depression and its ability to hold seasonal water.

a. Keep heavy equipment out of the pool depression at all times of the year. Rutting here could cause the water to drain too early, stranding amphibian eggs before they hatch. Compaction could alter water flow and harm eggs and/or larvae buried in leaf litter at the bottom of the depression.

b. Prevent sedimentation from nearby areas of disturbed soil, so as not to disrupt the pool's breeding environment.

c. Keep tree tops and slash out of the pool depression. Although amphibians often use twigs up to an inch in diameter to attach their eggs, none should be added, nor existing branches removed. If an occasional top does land in the pool depression, leave it only if it falls in during the breeding season and its removal would disturb newly laid eggs or hatched salamanders.

Shade Zone — *50 ft. buffer around pool edge*

Objective 2: Keep a shaded condition in this 50 ft. wide buffer zone around the pool depression. Amphibians require that the temperature and relative humidity at the soil surface be cool and moist.

a. Light, partial cuts which can maintain this micro-climate are acceptable; clear cuts are not.

b. Understory vegetation such as mountain laurel, hemlock, advanced regeneration or vigorous hardwood sprouts after a harvest will help to maintain this condition. Avoid leaving only trees with small or damaged tops, or dead and dying trees.

Objective 3: Minimize disturbance of the forest floor.

a. Operate in this area when the ground is frozen and covered with snow, whenever possible. When operations must be scheduled in dry seasons, keep equipment 50 feet away from the pool depression and winch out logs.

b. Avoid operating during muddy conditions which would create ruts deeper than 6 inches. They can be an impediment to migrating salamanders, some of which are known to use the same vernal pools and migratory routes for 15 to 20 years.

c. Minimize disturbance of the leaf litter and mineral soil which insulate the ground and creates proper moisture and temperature conditions for amphibian migrations.

Low Ground Disturbance Zone — *50-200 ft. from pool edge*

Objective 4: As above, minimize disturbance of the forest floor in this area.

a. Operate equipment in this area when the ground is frozen and covered with snow, whenever possible.

b. and c. Same as in 3 above.

d. Locate landings and heavily used skid roads outside of this area. Be sure any water diversion structures associated with skid trails and roadskeep sedimentation from entering the shaded zone and the vernal pool.

1) Landings

When determining placement and layout of landings, their size and number are minimized and they are located on soils that will support the logging equipment. Landings are permanent sites and are placed on level and well-drained ground whenever possible. Frozen soils are desirable because they must support heavy trucks, but these conditions cannot be assumed to occur for more than a month or two each year. When located on moderately drained soils, landings are constructed with natural and/or man-made materials that prevent rutting and maintain a workable surface. This generally includes the use of crushed gravel, which allows water infiltration and supports heavy equipment, and may also include the use of "geo-textiles", woven road construction fabrics that prevent mixing of gravel with the soils below. Landings will not be accessed by skidder or forwarder roads that direct water into the landing. An effective barrier is maintained between the landing and access road (road ditch, hay bales, etc.) and landings are required to be smoothed and seeded after use.

2) Skid Roads

Skid roads are designed to be reused and are therefore located on soils that can support the skidder, such as well-drained gravel or well-to-moderately-drained stony till soils. Some soils, regardless of their drainage capacity, are wet in the spring, early summer, and late fall and harvesting must be scheduled for dry or frozen conditions. Skid roads are cut out before use and limbs left in the road to protect the soil. Skid roads are relatively straight to avoid damaging roadside tree stems and roots, but they are not allowed to carry water for more than 100 feet. Continuous grades are deliberately interrupted to divert rain water off the road. Most skid road grades are less than 10%, but in some cases, climbing grades may reach a maximum of 20%. These steeper climbing grades are limited to 200 continuous feet. Downhill skidding grades are allowed up to 30% but for no more than 200 feet on grades greater than 20%. On skidding grades greater than 20%, which are not protected by frozen ground or snow cover, tree branches will be put on the road and other erosion-control measures taken as necessary.

Skidding distances are minimized to prevent excessive wear to roads unless they are protected by frozen ground, snow, or rocks. Skidder width and weight requirements are tailored to site conditions. The Division has rated all commercially available skidders by taking into account their horse power, weight, load capacity, tire size, and width to determine their suitability for logging on water supply watersheds (see Section V.B.4.c. for examples). Skidder widths range from 85-114 inches and loaded ground pressures range from 5-11 lbs/sq inch. Typically, machines with loaded ground pressures of 8 lbs/sq inch or less and widths of 102" or less are allowed on MDC watersheds. Skidding is stopped when rains or thaws make the soils unable to support skidders.

At the end of the logging operation or when work is suspended, skid roads are stabilized to prevent erosion. The construction of water bars accomplishes this task. On slopes greater than 10%, water bars are spaced every 50 feet and on slopes less than 10%, they are spaced every 100 feet. It is sometimes difficult to regularly space water bars due to rocky conditions and lack of places to discharge water, so spacing may vary. Water bars are designed to meet two criteria:

a. they must angle across and down the road to create a 3-5% pitch, and
b. they must discharge water to an area that drains away from the road.

A skidder can usually be used to construct water bars unless the soils are very rocky or ledgy. In rocky soils, they may have to be dug by hand. They do not have to be more than 6-8 inches deep,

including the berm, unless they have to deflect more than the skid road runoff (in which case depths are doubled). After completion of logging, water bars on skid roads are seeded during the growing season.

3) Forwarder Roads

Forwarder roads are located on soils that can support these machines. The layout of forwarder roads is more flexible than for skid roads because forwarders do not require straight roads. Forwarder roads can pass through the forest avoiding soft soils, trees, and sloping ground. Forwarder roads usually have less than a 5% slope with an occasional grade up to 10% for a maximum of 100 feet. Forwarder roads sometimes require rough preliminary grading to remove stumps and rocks. Forwarders were originally designed to stay on the road and pick up logs brought to the road by a skidder, but they also replace skidders when soil and/or vegetation conditions and cultural features cannot accommodate skid roads and skidder landings. In operations that combine skidders and forwarders, skidders operate the sloping and rough ground for distances of less than 1,000 feet, while forwarders operate on the more level terrain and handle long hauling distances. Water bar requirements for forwarder roads are the same as for skid roads.

4) Stream Crossings

Stream crossings are usually avoidable on MDC watershed properties. When streams must be crossed, frozen conditions are favored whenever possible. These conditions not only protect the actual crossing, but also protect the approach and limit the amount of soil carried in machine tires or on skidded logs.

Portable bridging is used to cross all streams with a continuous flow. This bridging consists of either pre-fabricated sections transported to the site (the Division has constructed portable bridge sections for use by private contractors), or site-constructed bridging. Past studies (Thompson and Kyker-Snowman 1989) have shown that machine placement and removal of crossing mitigation can move substantial sediments into the stream, especially where banks are steep or unstable. Therefore, it may be preferable in some conditions to construct mitigation on-site and without machinery. In either case, the bridging will be designed and constructed so as to prevent degradation of stream water measured downstream of the logging activity before, during, and after that activity.

Correct siting of crossing locations is important in order to avoid soft soils that the machine may carry onto the bridge and into the water. Chapter 132 requires that all crossings be marked with paint or flagging and carefully mapped prior to filing of a cutting plan. All crossings are made at right angles to the streamflow. If frozen conditions are not available, then banks and adjacent soils are protected with tops of trees, poles, or other suitable material. In all crossings, any mitigation that involves structures that obstruct streamflow is designed and installed to accommodate the 25-year stormflow for the upgrade drainage. All temporary crossing construction is removed at the completion of the operation, and the site stabilized. Division foresters supervise the design, construction, placement, and removal of bridging or other mitigation and the proper protection of approaches, prior to the commencement of logging on the site.

Crossings of small, intermittent streams subject to M.G.L. Chapter 131/132 protection (those portions downstream from the highest bog, swamp, wet meadow, or marsh in the drainage) are mitigated to prevent measurable downstream water quality degradation when these streams are flowing. These streams are only crossed without mitigation during frozen or dry conditions (when

they are not flowing). No intermittent stream crossing will be allowed that would result in rutting or disruption of stream bank integrity. Chapter 132 further requires that all streams, including intermittent streams downstream of the highest wetland, within 1000 feet of the reservoir high water mark must be crossed with portable bridging. Division foresters will monitor all unbridged crossings frequently, and discontinue or mitigate them if conditions deteriorate and downstream water quality is threatened.

In the past MDC has crossed streams on a very limited basis. For example, from 1978 to 1990, the Division conducted 130 logging operations on the Quabbin and Ware River watersheds that involved 12 stream crossings (7 were across existing culverts, two were mitigated with DEM-approved techniques, and three were crossings of intermittent streams in dry or frozen conditions).

Table 15 outlines the various stream crossing situations encountered on Division watersheds, and level of protection these crossings are given.

Table 15. Protection measures applied to various stream crossing situations.

"WETLAND" for this chart refers to bogs, swamps, wet meadows, and marshes; "MITIGATE" includes use of poles, brush, slabs, etc. placed in or beside a small stream to minimize equipment impacts on bank or streambed integrity; "BRIDGE" includes installed or site-built structures that are above the stream profile and capable of keeping all equipment and harvested products out of the profile

	Level of Protection		
Type of Crossing Situation	BMP's Only	Mitigate	Bridge
Intermittent stream, above the highest wetland in the drainage	✓		
Intermittent stream, downstream of highest wetland, when not flowing; crossing further than 1,000 feet from reservoir high water mark	✓		
Intermittent stream, downstream of highest wetland; crossing further than 1,000 feet from reservoir high water mark; when flowing		✓	
Any intermittent stream with unstable banks/approach; regardless of flow conditions		✓	
Intermittent stream, downstream of highest wetland, crossing within 1,000 feet of reservoir high water mark; regardless of flow conditions			✓
Continuously flowing stream			✓

j. Pollution Control

This section describes methods for control of petroleum product spills, human waste, and the disposal of rubbish generated by loggers and logging machinery maintenance.

Petroleum products: All machines are inspected by Division foresters for leaks prior to arrival and for the duration of their stay on the watershed. Checks are made of all hydraulic components, fuel tanks and lines, engine, transmission and axles. Trucks, forwarders, skidders and other equipment that carry petroleum products must have a minimum of 6 petroleum-absorbent pads (3'x 3') on the machine. Immediate action to contain and stop any petroleum spills followed by prompt notification of the forester is required. The forester in turn contacts MDC Environmental Quality personnel.

All petroleum products that are not in machine storage are stored in safe durable containers and removed from the watershed at the completion of each day. Petroleum storage is only allowed in tanks designed, manufactured, inspected, and certified for commercial use. No re-fueling or servicing is allowed within the 50 foot filter strip along water bodies or within 25 feet of any wetland.

Human waste: Human solid waste is not allowed to be deposited on the watershed. Contract specifications require the use of a portable bathroom facility (a minimum of a "Coleman" chemical toilet). The only exception to this policy will be the use of existing sanitary facilities on the watershed, which include those installed for recreational access. Where necessary and appropriate, the Division will install such facilities to accommodate truckers associated with logging operations.

Rubbish: All waste material, including parts, packaging, lubricants, garbage, sandwich wrappers, and other litter must be stored in appropriate containers and removed daily from the watershed.

k. Fire

Fire prevention concerns both the forest and machinery. MGL 48 § 16, a.k.a. the "Slash Law", adequately deals with the disposal of slash along boundaries, water bodies, wetlands, highways, roads and utility right-of-ways. Slash is not allowed within 25' of any stream; river, pond or reservoir. This law is also the Division standard.

Fires and pollution can be spread by machine fires. Fires on the machine can be prevented by keeping a leak-free, well-maintained machine and having the proper fire extinguishers on the machine. All machines are inspected for proper fire extinguisher and spark arresters by a Division forester before entering the site.

l. Vegetation

Avoiding damage to roots, stems and crowns of understory and overstory vegetation is essential in maintaining a protection forest. Damage can occur from unskilled tree felling, skidding, forwarding and the development of skid/forwarder roads. Most damage can be prevented by skilled loggers and foresters if the proper logging system is used. Division contracts include the right to suspend operations due to operator inexperience or negligence.

m. Cultural Resources

The protection of cultural resources fits well with watershed management because they both require low-impact logging systems. For example, small versatile equipment can reduce soil compaction and work around walls and foundations without damage. In many locations, there are no places for a landing due to cultural sites or poor soil conditions. Forwarders mitigate this problem by stacking logs on the roadside. The "preferred logging system" in these situations is a combination of cutting, lifting, or winching trees out, and forwarding them to an appropriate landing to meet cultural resource protection objectives (see Section V.D. for a more detailed discussion on this subject).

n. Aesthetics

Aesthetics can be affected by all of the practices described in all the above sections, and are the demonstration of workmanship quality. The maintenance of aesthetics reflects how the logger feels about his work and about the land on which he is working. This perspective cannot be forced, but it can be encouraged and learned. When work is done correctly it is not conspicuous, but when it is done carelessly, it is obvious to all. These are public lands and the public regularly passes through them either along public roads or on roads within the watersheds. Attention to aesthetics is important everywhere, but most important along traveled ways. All slash and debris from fallen trees is kept 20' back from the road's edge or on the back side of a bordering stone wall. Landings are cleaned of unmerchantable tree debris. Care is taken to maintain large roadside trees and to promote replacement trees.

5. Control of Harvest Operations Through Timber Sale Contract

a. Introduction

In conducting silvicultural operations that require the removal of forest products from the forest, Division policy is to protect watershed resources such as water quality, soils, residual trees, and cultural resources. Both the timber sale contract, discussed below, and the Best Management Practices presented in the preceding section address these concerns. In general, the timber sale contract specifies the performance standards, whereas the BMP's explain how these contract specifications are met.

The Contract consists of written specifications, pages detailing the forest products offered for sale, maps delineating the sale area, and a proposal page where a bid for the timber is entered and signed. The written specifications deal most directly with protecting watershed resources. Specifications consist of five parts: a. Contractual Specifications, b. Water Quality Specifications, c. Logging Specifications, e. Equipment Specifications and f. Bidding and Bond Specifications. Parts b., c., and d. pertain to protecting watershed resources.

b. Water Quality Specifications

These specifications are primarily concerned with petroleum leaks and spills and control of human waste. Petroleum products are required to be kept in suitable containers and removed from the

work site each day, unless stored in tanks designed for fuel, such as those on the logging equipment. Oil absorbent pads and blankets are required on site and with all equipment, in order to intercept and immediately control a petroleum spill. All associated refuse from maintenance and repair is required to be stored in appropriate containers and removed from Commission lands as soon as possible. Human waste is required to be deposited in Division toilets or toilets supplied by the operator.

c. Logging Specifications

These are concerned primarily with the process of cutting trees and removing forest products from the forest. The contract specifies conditions for lopping slash to enhance decomposition and reduce fire hazards. Specifications for keeping slash out of streams and back from access roads are described. The penalty for cutting unmarked trees is set at three times the value of the tree. Utilization standards (maximum stem diameters to be left unharvested) are specified for each contract in order to limit slash. Specifications to limit damage to residual trees and soils, especially in the felling and removal of forest products, are described. Locations for logging roads and landings are determined by the forester; the contract specifies the condition in which these areas must be left at the completion of the operation. The contract makes it clear that the logging operation may be suspended due to wet or extremely dry conditions, at the forester's discretion.

d. Equipment Specifications

These specifications limit the size of skidders and other equipment to minimize soil compaction and rutting and to minimize physical damage to residual trees and cultural resources. These specifications may require specific equipment due to the conditions of the lot. For instance, where it is difficult to place straight skid trails, or where dense regeneration is present, the forester may specify a that forwarder must be used and that skidders are not allowed. Where hauling distances to a truck landing are long, but the lot itself requires skidding, the forester may require that both pieces of equipment must be used. The Division also may require a tracked feller-buncher-processor on lots that have sensitive cultural resources requiring specialized tree removal, on soils that cannot support heavy equipment, or in stands with heavy forest stocking that cannot be thinned properly with standard equipment.

6. Internal Review and Monitoring of Forest Management Operations

The key to the proper protection and management of the resources under the care and control of the Division is its staff, and the care and expertise they bring to their work. The Division believes its staff of resource management professionals is unmatched in their experience, broad-based resource knowledge, resource conservation and watershed protection ethics, and sensitivity towards the resources with which they are entrusted. It is through careful staff selection and ongoing training that this staff has continued to grow and improve over its 25 year history.

Because the foresters walk each acre of land on which forest management occurs, the management controls enforced by this staff are of paramount importance. As the on-the ground implementers of the Division's land management plans and policies, the foresters' knowledge, and sensitivity to the various aspects of the watershed management plan have a direct bearing on the

ultimate success of the program. However, it is impossible for any one individual to assimilate all aspects of the great diversity of knowledge involved in the evolving fields of natural and cultural resource management. Therefore, the second key to implementing sensitive management is review by in-house experts in the various key disciplines of study in natural and cultural resources, and effective communication between these experts and the forest managers.

Within the Division, these supporting disciplines include wildlife biology, forest planning, water quality and environmental engineering, civil engineering, and cultural resource protection. Experts available outside MDC include rare species botanists and zoologists (Mass. Natural Heritage and Endangered Species Program) and cultural resources specialists (Massachusetts Historic Commission). The Division also has available a wide variety of experts conducting academic research on the watersheds at any given time, in part because of the research value of the resources under the Division's care and control. These professionals, and interested non-professionals who spend time simply exploring the watersheds, also contribute invaluable observations and input to the Division's understanding of the resource components and functions on the watersheds.

To efficiently and effectively coordinate and focus the above knowledge towards the improved protection of the water supply and other natural and cultural resources, the Division has developed the following procedure for the annual review of all forest management activities. These reviews are in addition to the general guidelines for cultural and wildlife resource protection listed in Sections V.C. and V.D.

a. Each December, the Division's foresters compile a plan of all possible forest management that could occur during the next fiscal year (July-June). The only operations not included would be emergency salvage after natural events. Each January, the foresters carefully map and describe the boundaries of each planned operation so that they are readily distinguishable on the ground (where boundaries are not easy to describe, they are marked with flagging). These outer boundaries may include internal areas where logging is restricted (vernal pools, stream filter strips, etc).

b. After mapping the areas where forest management is proposed, the foresters submit site maps and Project Description Forms (see Supporting Appendices: Project Description Form) for planned operations to the Division's Natural Resource Specialist responsible for forestry issues. This specialist digitizes the maps of the planned operations, calculates the total acres of these operations, the proximity of wetlands and identified critical cultural and wildlife sites, and checks the overall consistency of the operations with management plan silvicultural and resource protection objectives. After reviewing the proposed operations, the forestry Natural Resource Specialist then forwards copies to the MDC Chief Archaeologist, the Division's Natural Resource Specialist responsible for wildlife issues, the Massachusetts Division of Fisheries and Wildlife Natural Heritage and Endangered Species Program (Natural Heritage), the Division's supervisor responsible for forest engineering, and the Division's Environmental Quality engineering staff.

c. The Chief Archaeologist consults the Division's cultural resource maps and utilizes additional resources to ascertain if cultural resources may exist on these proposed logging sites. The cultural resource maps were compiled by consultants in projects completed in 1986, 1990, and 1994. These maps denote known and likely historic and prehistoric sites. Where forest management is planned for areas containing or likely to contain cultural resources, the

Chief Archaeologist gives foresters specific guidelines or measures to be incorporated during the planned operation to protect these resources.

d. Each Spring, the Division's Natural Resource Specialist responsible for wildlife issues reviews the planned forest management operations described on Project Description Forms. Where necessary, the wildlife specialist conducts site examinations. Local knowledge of state rare, endangered, and threatened species is referenced, as well as the location of any critical or important habitat features in the wildlife biologist's files. After completion of field work by the wildlife specialist, the foresters are given specific mitigation guidelines to be incorporated in the planned management, keyed to the flagging of any critical or important features on the ground where necessary. As an added resource, the foresters may reference the wildlife management BMP section contained in this plan (Section V.C.2.).

e. The Natural Heritage Program maintains geo-referenced database records of rare and endangered species populations and critical habitats. As part of the annual review process, the Division provides Natural Heritage with digitized map files of proposed operations. Natural Heritage then overlays their information with the operation boundaries and provides the Division with management recommendations for lots that overlap rare and endangered species habitat.

The Division, in conjunction with Natural Heritage, also contracts with a professional botanist to review all proposed Division lots for the presence of rare or endangered plant species. The bulk of this plant inventory occurs during May and June, although the botanist may make recommendations pending an additional survey for late flowering species, to be conducted in August, for a limited number of these operations.

f. Each spring, the Division's Environmental Quality staff reviews the planned forest management and, where necessary, conducts site examinations. The Environmental Quality staff may give site specific guidelines regarding special precautions designed to increase the protection of site water quality. In addition, the Natural Resources staff, with input from the Environmental Quality staff, has developed standard operating procedures related to protecting local water quality at forest management operations. These are included in Sections V.B.4. and V.B.5. The key to water quality protection is the vigilant supervision and follow up with water protection measures during the operation and after lot completion.

g. After incorporating the recommendations from the above reviews, the foresters lay out and mark the lot. At this time a Forest Cutting Practices Act (MGL Chapter 132) Cutting Plan is prepared (outlining skid roads and specific site impacts). After the lot has been advertised and awarded to a private contractor, the Forest Cutting Plan is submitted to the Department of Environmental Management (DEM) and copied to the local Conservation Commission. Chapter 132 requires DEM staff to conduct a site visit prior to the start of the operation, if wetland resources are involved. These regulations also require that Department of Environmental Management Service Foresters check all cutting plans against the Natural Heritage maps of rare and endangered species habitats and, if they overlap, submit these plans to Natural Heritage for review and comment.

Throughout the active operation, it is the responsibility of the forester in charge to continuously monitor compliance with water quality protection measures. In particular, these include stream crossings and work near wetlands, conditions of skidder and forwarder roads as well as main access roads, equipment maintenance, and the treatment and placement of slash. Upon completion of silvicultural operations, it is the responsibility of the foresters to check for full compliance with all contract specifications prior to the release of the performance bond and filing of final reports.

The Division Natural Resource Specialists support the work of the Foresters in a variety of ways, including overseeing periodic projects that monitor water quality adjacent to timber harvesting operations. Both staffs work together to collect, process, and analyze data for annual regeneration surveys, to document changes in the forest understory. These data are critical to monitoring the success of both silvicultural and deer impact control components of the management plan.

In addition, the Foresters work with the Natural Resource Specialists to track changes in forested areas relative to management plan objectives, utilizing a stand exam system designed to measure these changes. The stand exam system analyzes species composition and the distribution and density of tree sizes, and compares these to silvicultural objectives designed to meet the goals of the management plan for the particular area. This exam is utilized both prior to and following silvicultural treatment.

As the regulatory environment that affects the plan's implementation changes, it is the responsibility of the Natural Resources staff to incorporate these changes in the plan. This staff works to communicate these changes to the Foresters and others implementing the plan, and occasionally reviews watershed operations for compliance with these changes and with the commitments stated in the plan.

C. Wildlife Management

1. Assessment of Impacts of Planned Watershed Management Activities on Wildlife

The forest and other management activities proposed in this plan will have various impacts on Quabbin's wildlife community, mainly through the changes in habitat conditions that will result from that management. The Literature Review in the Supporting Appendices contains a general review of the scientific literature on the impacts of various forest management approaches on wildlife. In this section, the likely impacts of the specific approaches outlined in this plan will be discussed.

Wildlife populations at Quabbin have been impacted by both natural events and management activities and decisions since the creation of the reservoir in the 1930's. Indeed, it is likely that the most significant impacts to wildlife in the history of the Quabbin watershed system occurred during major events like the flooding of the reservoir, the 1938 hurricane, periodic fires, and other natural events. More recently, the loss of large numbers of hemlock trees and stands to various insects has influenced the value of those areas for wildlife. In contrast, the impacts on wildlife from forest management activities (at least on the scale conducted at Quabbin in the past) tend to be more gradual and/or localized.

Still, it is important to understand what these likely changes will be, so this next section will address the ways in which the present habitat conditions and wildlife community are likely to change as a result of implementing this management plan.

a. General Impacts

The Division's principal long-term forest management goal, to establish and maintain a forest cover consisting of many ages of trees of diverse native species on the vast majority of its land holdings, has several implications for wildlife. First, it means that Quabbin's wildlife community will continue to be dominated by species adapted to forested conditions. Species adapted to open land and blocks of early- or mid-successional habitats will continue to be uncommon, occurring only on the relatively small percentage of the watershed where those conditions persist or will be created. These will mainly be in conjunction with beaver-impacted areas, openings associated with developed areas (e.g., in Quabbin Park), and in "secondary use" areas designated for early-successional habitat creation. Since forest cover will occur over substantial portions of the landscape, "forest interior" wildlife species should particularly benefit.

The associated goal of enhancing structural and species diversity within the Quabbin forest should have the general effect of enhancing wildlife species diversity. This impact should be especially evident in the forest understory, since this habitat stratum or layer is largely lacking in much of the present forest. This change will occur gradually over the next several decades, as both the deer impact control and forest regeneration efforts proceed, but it should begin to be evident during this management period (i.e., 1995-2004). Species most likely to benefit from this change include various bird species that forage or nest in such low forest strata (e.g., black-and-white warbler, winter wren).

The establishment of a forest understory over tens of thousands of acres will constitute a major change in wildlife habitat conditions on the Reservation. However, it is important to recognize that this change will come about principally as a result of the deer impact control program. Forest management activities will serve to speed the process of understory development, but even in their absence, the process would still occur, albeit much more slowly.

b. Specific Impacts

A number of specific approaches for the modification of existing conditions on the Quabbin watershed were presented in Section V.B. These include:

- Preparatory and regeneration cuts in both plantations and native forest stands (including single-tree and small group removals);
- Site preparation;
- Planting;
- Reversion of existing fields to forest cover; and
- Roadside mowing.

Since each of these involves a modification of habitat conditions, they will all have corresponding impacts on the wildlife community. However, such impacts usually include both "positive" and "negative" components. For example, regeneration cuts will result in an opening of the forest canopy, which may adversely impact species that favor intact canopies (e.g., goshawk, Cerulean warbler), but should benefit species that utilize the low food and cover provided by the resulting regeneration (e.g., rufous-sided towhee, common yellowthroat). Likewise, mechanical site preparation may temporarily disrupt the habitat of various animals that live on or just under the forest floor (e.g., ovenbird, red-backed vole), but planting those same areas with species such as spruce will create new habitat conditions now in short supply on the watershed.

The majority of the forest management work outlined for the next decade involves preparatory and regeneration cuts in both plantations and native forest stands (see Section V.B.3.f.). In general, this should result in more open forest canopies with better-developed understories. However, the actual impacts of these cuts on wildlife will largely depend on the specific methods used in the harvest operations. For example, the single-tree and small group (i.e., 1/10 to 1/4 acre) methods should maintain the overall integrity of the overstory, while still increasing vertical diversity of the stand. Thus, overall wildlife diversity in such stands should increase, although certain species that require either open understories or dense canopies (e.g., goshawks, Acadian flycatchers) would likely decline.

In the limited areas where larger-group cuts (i.e., 1 acre or more) are utilized, the resulting conditions will include a more broken canopy and larger blocks of early-successional forest habitat. In these situations, there will be greater impact to those species requiring dense overstories or open understories, but early-successional species (e.g., rufous-sided towhees; chestnut-sided warblers) not likely to occur in the previous example would likely occur. Given the limited number and distribution of these more intensive cuts, there should be no concerns regarding forest fragmentation effects (other than some localized edge effects) associated with the planned forest management activities.

The treatment of open land outlined in this plan could also have a significant impact on wildlife. This treatment includes reversion of some current fields back to forest cover and planting of some open riparian areas. Fields and other upland open lands are in relatively short supply on MDC Quabbin lands, and open areas along drainage areas are very productive of wildlife. Thus, any loss of these habitats could be construed as a significant loss of wildlife habitat. The mowing of roadsides will help counteract this loss of openland somewhat, but the narrow strips of open habitat provided by roadside mowing will benefit only some of the species that presently utilize the larger openings on the watershed.

Several long-term effects will likely result from the programs in this management plan. For example, maintenance of multi-layered forest conditions such as those described in Table 10 will mean that more and more of the Quabbin forest overstory will become relatively open over the years. Thus, those species requiring dense, tall overstory conditions will continue to decline. However, since the vast majority of the watershed system will still retain a forest canopy (albeit a more open one), other forest interior species should not be adversely impacted.

Another long-term impact will result from the gradual reduction in the oak forest component on the watershed. Acorns constitute an important food source for many wildlife species. As the relative abundance of oak declines over the years, the resultant decline in acorn availability will undoubtedly affect the wildlife community. Some species (e.g., gray squirrels, white-footed mice, wild turkeys) will be impacted more than others. Still, it is important to realize that acorn production is inherently irregular, so these species are already being impacted by fluctuations in this food source.

2. Best Management Practices for Wildlife Management

The decision to manage for a multi-layered, diverse forest cover on the majority of the MDC's Quabbin watershed lands will largely dictate the general nature and composition of Quabbin's wildlife community in future years. However, since many species respond to fairly specific and small-scale habitat conditions, it is still possible to have positive impacts on those species by providing for those habitat factors during the planning, marking and supervision of logging operations. For example, the continued retention of downed logs, identification of future high-value cavity trees, or the enhancement of seep areas during management operations will continue to result in measurable wildlife benefits without altering the general management goals or methods of the management program in any appreciable way.

In this section, a number of guidelines, or Best Management Practices, are presented that will enhance or preserve particular characteristics or values of forest stands for wildlife. These guidelines are generally categorized as involving: identification of important habitat types; considerations during marking; and operation timing considerations.

a. Identification of Important Habitats

Certain habitat types are especially productive of wildlife, or hold particular value because of their relative rarity. The identification and protection of these habitats can have measurable wildlife benefits. This can be best accomplished during the planning phase of management operations (when both in-house and other state agency records and databases can be searched for the presence of these habitats), and during the marking of lots (when such habitat areas can be identified in the field). Examples of such habitats include vernal pools, seeps, fruit orchards, aspen stands and habitats of state-listed species of special concern.

Information on the location and use of many important wildlife habitats on Quabbin already exists, as a result of numerous surveys, studies and casual observations made over the years. Much of this information presently resides in MDC cabinets or computer files, but will be transferred to a GIS database during this management period. This will greatly facilitate its access and use during the process of reviewing proposed land management operations.

1) State-listed Species of Special Concern

The Natural Heritage and Endangered Species Program (NHESP) within the Massachusetts Division of Fisheries and Wildlife maintains a listing of all known and historical occurrences of plant and animal species that are considered endangered, threatened, or of other particular concern in the state. Each year, they publish an atlas containing a series of maps showing the general locations of these occurrences. State agencies, organizations or individuals planning to conduct land development or management activities can use these maps to determine if their planned project is likely to impact those species or their habitats.

The DWM cooperates fully with the NHESP in protecting the special concern species and habitats that occur on MDC watershed lands. As part of MDC's Internal Review and Monitoring of Forest Management (see Section V.B.6.), Division staff routinely check the latest maps published by the NHESP, and maintain regular contact with the NHESP staff when planning forest management operations, or when potential conflicts arise. The DWM also contributes new information to the NHESP database as a result of surveys and other discoveries of rare species on its lands.

In most cases, when a planned land management activity could potentially alter habitat conditions for a state-listed species, work in those areas is simply avoided. In other cases however, through discussion and agreement with NHESP staff, appropriate changes are made in the planned management activities to mitigate any potential impacts on the listed species.

2) Vernal Pools

Due to their limited distribution, temporal nature and the critical role they play in the life cycles of various amphibian and invertebrate species, vernal pools are considered to be critical wildlife habitats on MDC watershed lands. Indeed, many of the known occurrences of state-listed species of special concern on Quabbin are associated with vernal pools. Accordingly, these habitats receive special attention during MDC land management operations.

Many vernal pools only hold water for a few months during the year (usually during the spring), and are sometimes difficult to identify at other times. Thus, the Division has conducted

springtime surveys on the Quabbin watershed in recent years to locate and document animal use of these pools. These surveys have covered thousands of acres and identified dozens of vernal pools. In addition, recent aerial photograph interpretation conducted at the University of Massachusetts produced maps and locations of more than 500 "potential" vernal pools on the Quabbin watershed. Many of these locations will be field checked in coming years to ascertain their actual status. Locations of known vernal pools are transferred to compartment maps of the watershed, which are checked during the internal review process mentioned above. A GIS data layer will also be produced using locational and other information on the pools.

Various guidelines for forest management activities near vernal pools have recently been developed by wildlife and forestry professionals in Massachusetts (Figure 13). These guidelines are intended to: 1) maintain the physical integrity of the pool depression and its ability to seasonally hold water; 2) keep a shaded condition in the 50-foot buffer zone around the pool depression; and 3) minimize disturbance of the forest floor within 200 feet of the pool edge. The Division adheres to these guidelines during its land management operations, and also seeks additional input from the NHESP when operations are planned in the vicinity of vernal pools known to contain state-listed species.

3) Other Important Habitats

Various other important wildlife habitats are known to occur on the Quabbin watershed, and these can also be identified and protected or enhanced during the planning phase of management operations. These habitats include woodland seeps, fruit orchards, wildlife wintering areas, and stands of several tree species of particular wildlife importance.

SEEPS are areas where ground water percolates to the surface of the forest floor. These areas generally do not freeze and have minimal or no snow cover during winter months. Further, since they tend to occur in small depressions in the landscape, they often serve as "seed traps", in which nuts, seeds and other wildlife foods produced by surrounding trees and shrubs accumulate. These factors make these areas particularly valuable as winter feeding sites for a number of wildlife species (e.g., wild turkeys). Management considerations for seeps include: 1) continued protection of the actual seep depression from heavy machinery and disruption; 2) removal of slash and tree tops from the seep itself; 3) continued maintenance of mast-producing trees above and immediately around the seep area; and 4) removal of conifers on the south, but retention of conifers on the north and west sides of the seep.

ORCHARDS and scattered fruit trees occur throughout MDC watershed lands, and these hold particular value as wildlife food sources. These trees are retained if at all possible, and in many cases, adjacent competing trees are removed. In the past, the Division has also given orchards and individual fruit trees additional attention, such as pruning, fertilizing, and installation of tree guards to prevent porcupine damage. These practices will continue as time and staffing allow.

WILDLIFE WINTERING AREAS provide critical habitats for some species during what is usually the coldest and most physiologically demanding time of the year. Examples of important wildlife wintering areas on Quabbin include deer concentration areas (usually in hemlock stands or pine plantations), and dense conifer cover (e.g., spruce stands) that provides cover and shelter for various bird and mammal species. Many locations of these areas are already known, or can be identified from cover type maps or aerial photographs. Thus, their protection or enhancement can be considered during land management planning. In general, management goals in such areas include the

maintenance or improvement of the particular conditions of the areas that make them valuable as winter cover. This generally relates to the density of the canopy (and its role in reducing snow accumulations or temperature fluctuations) or the presence or density of lower vegetation (e.g., low, live branches that provide escape cover or protection from wind).

STANDS of several tree species tend to be of particular value to wildlife, and these receive special consideration during land management planning. For example, aspen stands in all stages of succession are used by a wide variety of organisms, from microscopic to mega-faunal. However, since aspen is short-lived and generally occurs only in early- to mid-successional stages, it is an uncommon species in the current Quabbin landscape. As deer impact control, and forest management aimed at stimulating tree regeneration progress, it should be possible to increase the occurrence of this valuable tree species on the watershed. Where it is possible and appropriate, aspen management in secondary-use areas is considered.

Spruce stands also have high wildlife value, both for the cover and the food they provide. However, spruce is also a relatively uncommon tree species on the watershed, comprising only 1% of the total forest cover (Table 3) on MDC properties. Thus, the maintenance, enhancement, and possible expansion of the existing spruce cover on Quabbin is one of the wildlife management objectives for this management period.

Yellow birch stands are also uncommon on Quabbin, but several studies have shown them to have higher than average wildlife value. These stands are often found along stream drainages, which tend to have high wildlife value of their own. Thus, these areas will also receive special management attention during this period.

b. Considerations During Marking

Many of the potential impacts of land management activities can be predicted and mitigated during the planning phase of those operations. However, the occurrences of specific wildlife species or habitats, plus the likely impacts of the planned operation on them, may not be discovered or determined until the actual marking or field preparation for those operations. For example, locations of raptor nests or large cavity trees may not be discovered until the forester begins to mark the area for a silvicultural operation, when each acre and the trees on it are scrutinized individually.

In this section, guidelines are presented that are used in identifying and mitigating potentially adverse impacts on important wildlife habitat features in management areas.

1) Snags and Cavity Trees

The cover and food provided by snags and cavity trees represent important components of the wildlife habitat value of forest stands. Approximately one-quarter of the forest wildlife species in the northeast utilize snags or cavity trees for nesting, resting, or feeding (DeGraaf and Shigo 1985), and the abundance, distribution, and general welfare of these species is closely tied to the availability of suitable snag and cavity trees.

In managing for snags and cavity trees (sometimes referred to as "wildlife trees"), it is important to recognize several points. First, different wildlife species have different requirements regarding wildlife trees. Size, for example, is an important factor. A black bear needs a different-sized cavity than a chickadee. Likewise, a pileated woodpecker needs a sturdier feeding substrate than a nuthatch. In general, "the bigger the better" when it comes to the value of snags and cavities. However, retention of a variety of sizes during management operations will result in greater wildlife value of those areas for cavity and snag users.

The availability of suitable snags and cavities is often a limiting factor in the distribution of cavity-using wildlife. However, many of these species are also territorial, at least during the nesting or denning season, so there is a point of diminishing returns beyond which the provision of additional cavity trees will not by itself increase animal populations. Large cavities tend to be less common than smaller ones, and the larger wildlife species that utilize these large cavities tend to have the largest territories. Therefore, recommendations for cavity management often focus on the number of large-diameter cavities per unit area required to maintain viable populations or target densities of selected large cavity-users. Tubbs et al. (1987) reviewed various such recommendations, and found that studies in the northeast reported that large-cavity (i.e., >18") densities of 1 per 4-5 acres were needed to sustain populations of larger cavity-users.

To provide for the cavity requirements of all likely cavity users in a management area, much higher cavity densities are required. Recommendations of up to 10 cavities per acre are sometimes found in the literature. Provision of an average of 5 cavity trees per acre fits well within the typical range of management recommendations for this region, and should provide for moderate population densities of most local cavity users.

The distribution of snags and cavity trees within a management area is seldom uniform. Some forest stands will have an abundance of them, while others have few. Thus, in managing for snags and cavity trees, it will sometimes be appropriate to maintain many more than the recommended 5 per acre, while in other areas, only much lower densities will be possible. A general rule of thumb for snag and cavity management is thus to leave valuable ones wherever they exist (Healy et al. 1989).

Thus, good wildlife tree management requires the ability to identify valuable existing and potential future snags and cavity trees. Following are several guidelines for choosing these:

- cavities in live, otherwise vigorous trees are particularly valuable, since they have a long life-expectancy;

- different tree species have different decay rates, thus affecting the length of time they are usable as snags or cavity trees. In general, red maple, aspen and most birches decay quickly; sugar maple, oaks and hemlock decay more slowly.

- visible defects, such as butt rot, burls, cracks, and dead or broken limbs or tops usually signify good potential cavity and foraging sites.

2) Downed Woody Material

A number of studies have demonstrated the value of downed woody material in forested areas for wildlife. Downed logs serve as feeding substrates for insectivorous species, and are also important in moderating or buffering moisture and temperature fluctuations. Invertebrates and amphibians are particularly responsive to the presence of downed woody material in forest stands, and these species serve as important food sources for a number of other species as well.

Traditional forest management practices tend to leave little in the way of downed logs, especially large ones, in managed areas. Thus, the provision of this important wildlife habitat component must be the result of a conscious effort to provide it. While there are no established guidelines for the number or size of downed logs to leave, a general goal of leaving several per acre, on average, should result in measurable wildlife benefits. As with the issue of snag and cavity tree management, the actual distribution of downed logs across a forest stand will likely be irregular. Large logs are especially valuable. Amounts of downed logs left after various logging operations at Quabbin will be documented and compared to sites where silviculture does not occur, in order to better specify management practices for downed logs.

3) Raptor Nests

A number of raptors, and other large uncommon bird species, are known to nest on Quabbin. Several of these are listed as Species of Special Concern (e.g., Cooper's Hawk, Goshawk) and thus will receive special attention in the Division's management activities. However, several other species (e.g., Turkey Vulture, Common Raven) are relatively uncommon nesters in Massachusetts, and thus will also receive special attention. Many of these species construct or use relatively large stick nests located in forested areas, and these are often encountered during marking and other management operations.

In determining the appropriate course of action when large stick nests are encountered, it is desirable to first determine: 1) if the nest is active, and 2) if it is active, which species is using it. Active nests usually look different than inactive ones, and tend to look more "solid" and often have evidence of "fresh" vegetation in the bowl or at the edges of the nest. However, since the nests of many species (including common ones such as crows) look very similar, and since some species (both avian and mammal) will use nests previously constructed by other species, it is often difficult to determine which species is using a nest. Whenever possible, it is desirable to seek assistance from an experienced birder or biologist in making this determination.

As with almost any other group of animal species, raptors and other large forest-nesting birds vary widely in their sensitivity and reaction to disturbance and habitat alteration near their nest site. Thus, suggested mitigation measures will also vary with the species involved. In general, the nest tree itself, plus a cluster of trees surrounding it, will be retained. For certain "listed" species, this cluster may encompass a substantial distance around the nest. Timing of management operations is also of concern in such situations; disturbance will be minimized near the nest until after the young have fledged.

4) Group Selection Considerations

When marking areas for larger group selections (i.e., openings one acre or more in size), consideration of several factors can greatly enhance the wildlife value of the resulting habitats. These include: 1) leaving occasional snags or perch trees in the opening; 2) leaving occasional downed logs in the opening; and 3) creating a "feathered" edge between the opening and the surrounding forest. The first two practices will add important habitat components to the resulting opening, while the latter should result in reduced predation on nests in or near the forest opening edge.

5) Miscellaneous Considerations

A number of other specific wildlife considerations will also be incorporated into the marking and preparation phase of management activities. For example, white oak trees produce particularly valuable acorns for wildlife, so these trees will continue to be favored whenever possible. Likewise, hickory and beech trees also produce important wildlife mast. Since production of nuts by different species is not usually synchronous, providing for a diversity of mast-producing trees in a management area will generally result in greater year-to-year consistency in production of some form of hard mast.

Decisions about which individual trees to mark for cutting should also include consideration of disease and/or insect susceptibility. For example, individual beech trees can be resistant to scale disease, and thus are much more likely to survive and produce nuts that are valuable for wildlife. Thus, if vigorous, non-scaled beech trees are consistently favored, over time this should result in a beech component that is more scale-resistant (and more productive of beechnuts) than would otherwise be present. Further, since beech is not a particularly valuable tree to loggers, the larger-diameter, scaled trees can be cut and left as downed woody material, thus providing additional wildlife benefit.

The Division's silvicultural practices generally include the cutting of trees that are considered to have weak crown forms that are more susceptible to damage. However, some of these trees have particular wildlife value and Division foresters leave some of these trees uncut for this reason. For example, trees growing on an angle (sometimes referred to as "hurricane-tipped" trees) serve as travel ways for several species of arboreal mammals, providing easy access to the forest canopy. Similarly, older trees with many large stocky limbs often contain protected crotches used by many species of both birds and mammals as nest sites. Such trees also have high value often as potential cavity trees. Although it is not necessary to retain all such trees, it is nonetheless important to retain some during marking and harvest operations.

Particular mixes of tree species can also hold high wildlife value. For example, mature oak trees within hemlock or other conifer stands provide an important food source within protected wintering habitat. Conversely, small pockets of hemlock within predominantly hardwood stands can serve as important wildlife cover. Both these habitat conditions will receive preferential treatment whenever possible.

6) Data Gathering and Record-keeping

Division foresters and other land managers spend substantial amounts of time walking, observing, and assessing large acreages of the Quabbin watershed. In doing so, they are likely to

observe much wildlife and discover important wildlife habitats. These observations represent a major source of useful information on the wildlife resources of Quabbin, and will greatly enhance future efforts at mitigating potential wildlife impacts of management activities. It is important that such observations be conveyed to the Division biologist so that records can be kept updated and current.

c. Timing of Operations

Important wildlife habitats can be identified and protected from alterations that decrease their wildlife value, but effective mitigation of adverse wildlife impacts must also take into consideration the timing of management operations. It would be counter-productive, for example, to protect a clump of trees around a Goshawk nest site, but conduct the harvest operation around that clump in the middle of the nesting season. Goshawks and some other wildlife species (e.g., Bald Eagles, Great-blue Herons, Coyotes) are particularly sensitive to human activity during the nesting or denning seasons.

Eagles and herons tend to nest in traditional sites, thus it is generally easy to avoid those areas during the nesting season. Unfortunately, with many other species, the presence of a nest or burrow is sometimes not discovered until the operation has begun. Since logging operations on DWM lands are often restricted during the spring months, such conflicts are uncommon. When they do arise however, efforts will be made to: a) assess the nature of the nesting/denning activity (i.e., what species is involved? what stage are they at (e.g., incubation, brooding, etc.)? how did they respond to the initial disturbance?); and b) determine what options are available to avoid further disturbance during the rest of the nesting/denning period.

Other management operations can be equally disrupting to wildlife if conducted at the wrong times. For example, mechanical site preparation or field maintenance operations (whether through mowing or burning) will almost always be disruptive for some species, but especially so during spring and early summer months, when nests, active burrows, and/or young animals are often found in those areas. Whenever possible, such management operations will be conducted later in the year.

Management activities in wintering areas can also be particularly disrupting to some wildlife species, since that time of year is already very physiologically demanding. In general, it is best to avoid operating in or near seeps, and other identified wintering habitats during certain critical times of the year.

In other cases, it is preferable to conduct management work during the winter months. This is true, for example, for logging operations around vernal pools. Winter logging in those areas would minimize the rutting and other disruption of the forest floor that can interfere with the use of such areas by amphibians.

It is clear that management operations at almost any time of the year could possibly be disruptive to some species in some area. However, in many cases, the positive impacts of those operations on wildlife or watershed protection might far outweigh the adverse impacts. Since all impacts cannot be avoided everywhere, the Division will strive to: a) continue to gather data on the more critical or sensitive wildlife habitats on the watershed; and b) assess the potential impacts of operation timing on a case-by-case basis so that impacts to special concern species, major impacts, and impacts that could easily be avoided by shifting the timing or location of the operation will receive proper consideration.

3. Population or Impact Control Plans

Certain wildlife species can have substantial impacts on water quality or watershed conditions. Although the Division's general rule is to not interfere with wildlife communities, when wildlife activity directly impacts water quality, watershed infrastructure, or other significant watershed resources, control measures may be necessary. On the Quabbin watershed, issues of particular concern regarding wildlife include white-tailed deer and their impact on forest regeneration and other vegetative conditions, the impacts of beaver on water quality and wetland and riparian zone conditions, the use of intake areas by roosting gulls and geese, and the impacts of burrowing animals on dam and dike integrity and function. Each of these will be discussed below.

a. White-tailed Deer

White-tailed deer impacts on forest regeneration and other vegetation on Quabbin Reservation have been well-documented over the years (see for example, Jones (1951); Healy et al. (1987); Kyker-Snowman (1989)). Concern over the long-term consequences of these impacts on water quality led to the decision, in 1990, to implement a deer impact control program on the Reservation. This program consists of four main elements:

1. controlled public hunting in selected areas;
2. small-group supervised hunting on Prescott Peninsula;
3. experimental electric fencing; and
4. various changes in MDC's land management program.

These elements are further described in MDC's "Quabbin Reservation White-tailed Deer Impact Management Plan" (MDC 1991).

Actual implementation of this program began in the fall of 1991, with the first-ever public deer hunt on the Quabbin lands inside of the highways that surround the Reservoir. This hunt was held on a 9,000 acre area on the west side of the Reservoir, and resulted in a substantial reduction in the deer herd there. In 1992, this same area was hunted a second time, and the first group-supervised hunt was held on Prescott Peninsula. Controlled hunts were carried out in these same areas in 1993, as well as in the Swift River, West Branch drainages (New Salem) and the Eastern drainages (Hardwick). The Swift River, East Branch drainage (Petersham) was added in 1994. These hunts were very effective in reducing deer population numbers. Future hunts will be held when and where they are considered necessary based on yearly assessments of both deer herd and regeneration conditions. Further, a major review of the program will be conducted following the 1996 hunts in order to evaluate program success and impacts, and to assess future needs.

Electric fencing to reduce deer impacts on forest regeneration has been used on a small scale on Quabbin since the mid-1980's. However, the experimental fencing program described in the 1991 Deer Impact Management Plan called for expansion of this small-scale fencing to include more exclosures and larger acreages. In early 1992, the Division solicited bids for the first of these larger experimental fences - a 100-acre exclosure to be built in Quabbin Park. A contractor was selected, and this fence was erected in the spring of 1993. Through the same process, three additional 100-acre fence exclosures were erected in Quabbin Park in the fall of 1994. The Division will complete tree planting and may conduct non-commercial regeneration cuttings in the area of these exclosures,

wherever vertical forest structure is desired but lacking. Additional exclosures may be put out to bid pending evaluation of the success of the first four 100 acre exclosures.

The final element of this impact management program included an evaluation of all Division land management activities on Quabbin to identify and modify those activities that might produce new deer foods (and thereby stimulate deer herd growth) during the herd reduction phase. Given the early success achieved in herd reduction in the program, the Division will begin silvicultural efforts to encourage regeneration in those areas where deer impact control has entered the maintenance (rather than the initial reduction) phase of the program.

b. Beaver

1) Introduction

The 1986 amendments to the U.S. Safe Drinking Water Act were in part a reaction to the perceived threats to drinking water quality posed by *Giardia lamblia*. Since beaver are capable of carrying this organism, and are semi-aquatic, their presence in public drinking water reservoirs is of particular concern to watershed managers. Consequently, the Watershed Protection Plan developed for Quabbin directs the MDC to monitor and study the impacts of beaver activity on water quality and public health. An earlier portion of this plan (Sections II.C.2.a.) described the status of the Quabbin beaver population; the range of impacts associated with beaver populations on a water supply watershed are addressed in the Supporting Appendices.

Beaver numbers have undergone a dramatic reduction on the Quabbin Reservation since the population peaked in the early 1980's. Based on complete censuses of active beaver sites on Prescott Peninsula, the population is now approximately one-quarter of its 1981 size. This reduction has been due, at least in part, to the effects of deer browsing around abandoned beaver ponds. This impact has effectively precluded the regrowth of hardwood tree species that typically occurs following beaver abandonment, and which makes those sites suitable for colonization again. However, as deer population reduction continues on the Reservation, it is likely that habitat conditions will improve, and the beaver population will increase again.

Site selection by beaver is largely dependent on geomorphological features of the landscape, thus there is usually a limit to the area that can potentially be affected by beaver. Johnston and Naiman (1990) found that following 20 years of colonization, a "threshold" of new colony formation was attained, beyond which new pond creation decreased substantially. A similar pattern has been observed during the annual beaver surveys on Prescott Peninsula, and it is likely that most potential beaver sites (including reservoir shoreline) have already been occupied and altered on Quabbin. Future beaver activity on the Reservation will largely be restricted to re-occupation of those sites already altered.

2) Overview of Impacts

The impacts associated with beaver activity can be substantial and far-reaching. From a watershed management standpoint, both positive and negative impacts can be identified. When dams remain intact, beaver ponds play a role in regulating stream flow and ground water levels and

sequestering nutrients and sediments. However, beaver activity may also result in increased water temperature, color, total organic carbon, turbidity, bacterial counts, and risk of water contamination (e.g., with *Giardia lamblia*). Several recent studies at Quabbin have already documented the presence of *Giardia* in beavers and beaver ponds (e.g., von Oettingen 1982; Speranza 1988).

In many cases, whether beaver activity is viewed as positive or negative hinges on the proximity to intake structures, the integrity of the dam, and the hydrology of its upstream watershed. Thus, site-specific, case-by-case assessments must be made to determine the desirability of beaver activity in any particular location.

3) Management Policy

In the past, several control measures have been employed to deal with beaver problems at Quabbin. These include live-trapping and relocation, fencing, and installation of flow control devices. These efforts have been geared towards:

- discouraging beaver occupation in the vicinity of water intake facilities, and

- allowing beaver occupation, but controlling flooding or other beaver damage, in areas further from the intakes, but where other watershed resources (e.g., roads or shade trees) were being threatened by beaver activity.

Due to the potential benefits of beaver activity - both from a watershed and general ecological perspective - this general policy of allowing beaver occupation, except in sensitive watershed areas, will be continued during this management period. The following are examples of situations or areas in which beaver activity may be discouraged or mitigated:

- beaver dams on unstable or flashy streams with a history of, or potential for, regular washouts,

- beaver activity that threatens rare or uncommon plant or animal communities,

- beaver activity that precludes the use of access roads necessary for watershed maintenance, management or protection,

- beaver activity that threatens the proper functioning or structure of dams, culverts, and other parts of the water supply infrastructure and

- situations where water quality data alert Environmental Quality staff to potential risks associated with beaver activity.

When a decision is made that control of beaver activity is needed in a particular location, a determination will be made concerning the most appropriate control method. Possibilities include: flow control devices, dam stabilization, individual tree protection, or lethal removal of beaver. In all cases, non-lethal methods will be utilized where and when they are appropriate. Appropriate permits will be obtained from the MDFW when necessary (e.g., when sections of beaver dams must be removed for the installation of flow control pipes).

When lethal removal in required, the Division will contract with licensed trappers who will remove the beaver during the regular Massachusetts trapping season (November through February). Only one trapper will be used for a specific removal site, and a permit will be issued for that location only. MDC will pay a trapper if none is willing to remove the beaver without compensation (e.g., due to low pelt prices). If situations arise at other times of the year, in which the nature of the problem necessitates a more immediate response, MDC will request permission from MDFW to remove beaver using Division staff.

4) Studies

The MDC/MWRA Watershed Protection Plan, necessitated by the 1986 amendments to the U.S. Safe Drinking Water Act, concluded that while beaver dams are not a significant threat to water quality at Quabbin Reservation, a study of the potential threat posed by washouts or removal of beaver dams should be conducted (MDC/MWRA 1991). A proposal aimed at addressing these and related concerns is described more fully in section VI.A.3. This study would include:

- an assessment of the amount of riparian zone in beaver flows, utilizing information from recently-taken orthophotos,

- an inventory of beaver dams for structural stability taking into account upstream watershed size, stream hydrology, pond volume, characteristics of the stream channel below the pond, and structural characteristics of each dam,

- monitoring of *Giardia*, *Cryptosporidium*, total organic carbon, and other appropriate water quality parameters on selected beaver flows near intakes (as recommended in the Sanitary Survey for the Quabbin watershed done in 1992) and which represent the main categories of beaver flows in the watershed, with a goal of setting a "no beaver" zone around intakes,

- annual ground and aerial inventories of Quabbin to locate new or existing beaver activity, and

- an assessment of the recovery of forest regeneration in abandoned beaver flowages.

As this and other studies on beaver impacts provide new information on the subject, appropriate modifications will be made to MDC's beaver management policy.

c. Gulls and geese

The Division has been monitoring gull populations at Quabbin since 1990. In the past four years, the Division has become concerned that periods of high fecal coliform counts in water sampled at the Chicopee Valley Aqueduct (a water supply with a current waiver from filtration under the new federal drinking water standards) coincide with periods of high concentrations of gulls (principally Herring, Great Black-backed, and Ring-billed gulls). For the past three years, the Division has coordinated water sampling and gull counts during fall months. Water quality analyses revealed that gulls were responsible for high bacteria levels.

Past studies have shown that the number of gulls using the reservoir starts increasing in the late summer, and reaches a maximum in early winter. Numbers drop again when the reservoir freezes (usually in mid to late January). Gulls typically leave the reservoir soon after daybreak, spend most daylight hours at local landfills and other feeding areas, and return to the reservoir in late afternoon. Accordingly, gull control efforts are mainly conducted during late afternoon and evening hours during the fall and early winter months.

In January, 1991, Division staff completed a report that reviewed the professional literature regarding gull pollution and gull control. This report included the following recommendations:

a. MDC should more specifically identify the landfills used by gulls that roost on the reservoir, and work with other governmental bodies to reduce gull access to those concentrated food supplies, and

b. The Division should prepare to conduct a short-term gull control program for the fall of 1992. This program should be multi-faceted, as it is unlikely that a single approach will be successful. The program should focus on gull disturbance and harassment rather than lethal methods, which have not proven effective.

A gull harassment program was begun at Quabbin in the fall of 1992. The gull control program is a cooperative effort among MDC Environmental Quality (EQ), Natural Resource (NR) and Maintenance staff at Quabbin. EQ and NR personnel supervise the daily harassment and gull counting efforts, with much of the actual work being carried out by Maintenance personnel. The program is built around a combination of human presence and pyrotechnical scaring devices. Typically, two laborers use a boat to "herd" the gulls away from the intake area. "Shell-crackers", fired from a 12-gauge shotgun, are also used to further harass the birds and encourage them to roost elsewhere. Care is taken not to "disperse" the gulls, but rather to herd them towards the alternate roost sites, which are several miles north of the CVA intake. The boat stays on the water until dark, when the gulls have generally settled in for the night.

Control operations are conducted as necessary throughout the week from October until the reservoir freezes. On occasions when weather or ice conditions preclude boat use, staff have conducted control efforts from the shore of the reservoir, both near the intake itself and from the western shore of the Reservoir. As the reservoir freezes over (usually in January), the Division relies increasingly on shoreline-based methods of control.

The 1992-93 program of gull harassment was successful, with only one exceedance of the federal drinking water standard of 20 fecal coliform bacteria colonies per sample, even though large concentrations of gulls had been roosting at the Reservoir. Similar success was achieved in the 1993-94 season, although adverse weather conditions that precluded boat use for several days resulted in several violations of the bacteria standard. In 1993-94, the Division expanded the program to a seven day per week operation and began a program of harassment at local landfills to supplement the reservoir program. The Division will continue the gull harassment program in future years and continue to review and examine new ways to minimize water quality risks from gulls (including assisting and training of landfill personnel in techniques of gull harassment, use of improved equipment for playing recorded bird distress calls, and the use of a hovercraft during periods when the reservoir is frozen and boats can no longer be used).

Canada geese also use the reservoir during the fall and early winter months when there is concern about increased bacterial counts, although they occur in much lower numbers than the gulls do. However, as the non-migratory population of geese continues to expand in the state, future water quality concerns could arise from the use of the reservoir by these birds. Annual goose surveys have been conducted at Quabbin for the past 5 years, and these will continue in an effort to monitor their numbers. If and when the results of these surveys, plus water quality data indicate that a problem is developing, appropriate control measures will be implemented.

d. Burrowing Animals

Burrowing activity of small and medium-sized mammals such as woodchucks, voles, and moles can have detrimental impacts on the integrity of dams, dikes, and other watershed structures. When engineering or sanitary surveys conclude that such activity is detrimental, appropriate measures will be employed to rectify those situations. These measures may include live-trapping or lethal methods to initially remove the animals, followed by habitat modification designed to prevent, or at least minimize future occupation of the site.

The Division has already worked closely with USDA Animal Damage Control specialists in dealing with animal burrowing situations, and will continue to do so, as well as seek the advice of MDFW and other local experts in developing long-term management solutions to these problems.

4. Active Management to Enhance Habitat for Selected Wildlife Species

A number of native wildlife species in Massachusetts are listed by the NHESP as "Special Concern" species. Various other wildlife species may not appear on the official list of special concern species, but are nonetheless deserving of special management attention because they are uncommon, or declining on a regional basis. In order to enhance the conservation of such species, the Division will actively manage certain areas specifically for them. In general, this active management will largely occur on those areas determined to be "less critical" for water supply protection (i.e., secondary-use areas), as determined by the sub-basin analysis procedure outlined in section V.E.

The process used to arrive at management decisions in these areas is essentially two-fold: 1) select appropriate species to manage for; and 2) assess the habitat condition and capabilities of the designated secondary-use areas to find appropriate matches with the habitat requirements of the selected species. For example, if a selected species required early-successional hardwood-sapling habitat, Division staff would likely choose a secondary-use area with pole-stage or mature hardwood growth in which to create those habitat conditions, rather than choosing a mature pine stand. Such decisions will allow for an efficient use of the Division's resources while still providing the needed habitat conditions for the selected species.

The selection of species is being accomplished by seeking input from various agencies, organizations, and individuals with knowledge about the status, history and trends of local, native wildlife species. The selected species may include some that are officially listed by the MDFW as endangered, threatened, or of special concern in the state, or may include species that are not on that list, but are still in need of some direct management attention due to regional declines, or other specific circumstances. An important part of this selection process will be the results of an ongoing

effort, as part of the Partners in Flight program, to generate a list of neotropical migrant bird species that are of special concern in Massachusetts. When this list becomes available in early 1995, Division staff will consult with the Massachusetts Partners in Flight committee concerning appropriate choices of species to receive direct management attention.

Once this list of selected species is generated, habitat associations for those species will be determined from the scientific literature, and species with similar habitat requirements will be grouped. These groupings, along with the habitat capabilities of the secondary-use areas, form the basis for final decisions about where and how to manage for which species. Management recommendations and plans will then be developed for those areas, and incorporated into the land management program. Efforts will also be made to monitor the progress of the habitat creation, and the response of the selected species to the management.

Work is currently progressing on both the selection of species and on the identification of secondary-use areas in which most of the management for those species will occur. To date, input has been sought from the Massachusetts Natural Heritage and Endangered Species Program, the U.S. Fish & Wildlife Service (USFWS), the U.S. Forest Service, the Massachusetts Audubon Society, and The Nature Conservancy. Much of the focus has been on bird species, since a substantial amount of data is available, and habitat associations are often clearly defined for many birds. Regional data from the annual Breeding Bird Surveys, conducted under the direction of the USFWS, have also been reviewed.

The feedback so far has identified various early-successional species (e.g., rufous-sided towhees, field sparrows, golden-winged warblers) and several mature-forest species (e.g., Cerulean warblers, wood thrushes) as potential candidates for direct management attention.

Both of these groups represent appropriate choices for secondary use management since neither is likely to benefit from the overall land management approach proposed in this plan. The first group generally utilizes the earliest stages of forest succession, that usually result from an even-aged management approach. The second group favors the intact-canopy/open-understory conditions typical of the later stages of even-aged forest management. Except for the blocks of habitat resulting from full overstory removals proposed in this plan on less than 1% of the managed area, little habitat for these selected species would otherwise be present on Quabbin in future years.

Early forest-successional habitats have been declining in New England for the past 20 years (Brooks and Birch 1988), so it is not surprising that the wildlife associated with such habitats are showing up on the list of selected species. Unfortunately however, early forest-successional stages are short-lived, so the maintenance of such habitats generally requires fairly intensive management efforts. A short-rotation, even-aged management program in hardwood stands, with successive cuts concentrated in relatively small geographic areas, is perhaps the best approach to provide some long-term maintenance of such habitat types.

Management for Cerulean warblers, wood thrushes, and other mature forest species, should be much easier to accomplish, since these conditions currently exist on much of the watershed. However, as the combined effects of deer impact control and the general watershed forest management program proposed in this plan begin to alter habitat conditions on the watershed, the amount of suitable habitat for these species will decline. To help mitigate this, certain secondary-use areas should be maintained in intact-canopy condition. Further, some of the even-aged stands created for the early-successional species discussed above could be allowed to succeed to late-successional stages. This should assure

the availability of these habitat conditions in future years, after the existing late-successional stands have begun to break up.

Although designed primarily to provide habitat for a small group of selected wildlife species, the two management recommendations described above will have the added benefit of generally diversifying wildlife habitat conditions on the watershed.

D. Protection of Cultural Resources

The Quabbin watershed is rich both in its historical and pre-historical resources. Accordingly, safeguards have been build into the Division's land management program to protect cultural sites and artifacts, both through the identification and mitigation of possible impacts, and through a program of proactive vegetative management around significant historical sites.

1. Review of Proposed Silvicultural Projects

Without appropriate controls, forest management programs can be detrimental to archaeological resources. Modern harvesting methods employ a wide range of heavy machinery, some of which, because of weight distribution and/or tire characteristics, can do irreparable damage to prehistoric sites. Skidding logs can further disturb the soil. Operations also entail clearing areas for landings, turn-arounds, and access roads. Those archaeological sites that lie closest to the surface can be obliterated by such activities. It is these same type of sites - those that are the youngest in time (i.e., the Early, Middle and Late Woodland) - that were most susceptible to destruction by the plow of the local farmer, and thus represent a relatively scarce piece of the archaeological record.

Accordingly, the foundation of MDC's Cultural Resource Management Program at Quabbin is a process for reviewing proposed silvicultural operations. The review involves evaluating and assessing the impacts that harvesting could have on archaeological resources should they exist at any given operation. This process has been developed over the past three years, and is formalized in this section.

a. Project Description Forms

After marking the boundaries of a planned silviculture operation, the Quabbin foresters submit a *Project Description Form* to the Chief Archaeologist for in-house review. The form provides a detailed narrative of the proposed operation including: location and size, description of topography, forest cover and soils, goals of silvicultural operations, equipment limitations, notable historic features, plant and wildlife communities, and hydrology.

The primary analytical tool employed in the review of impacts to prehistoric archaeological sites is the evaluation of *site location criteria,* which are discussed below.

b. Site Location Criteria

1) Prehistoric Sites

At no time in prehistory did human populations roam haphazardly and endlessly across the landscape. Even Paleo Indians, who were the first human occupants of New England approximately 12,000 years ago, are believed to have maintained an economic subsystem that involved a seasonal pattern of restricted wandering within loosely defined territories (Snow 1980:152). Over the next 10,000 years, sea levels rose and the forests and vegetative communities became more constant. During this time, Native Americans adapted their tool kit and strategies in order to take advantage of the new resource mixes and opportunities the new environmental conditions afforded. Thus, the pattern of habitat use, and consequently the locations of prehistorical sites and artifacts are largely predictable.

The key criteria for determining the archaeological sensitivity of a given site include:

- degree of slope (i.e., slope < 5 - 7 degrees);
- presence of well-drained soils; and
- proximity to fresh water (i.e. within 1,000 feet).

Other variables such as aspect, availability of stone suitable for tool-making, and elevation above sea level, may also be important. When one or more of these criteria are met, the site of the proposed silviculture operation is considered to have been an attractive location for Native American habitation or subsistence activities, and are thus classified as *highly sensitive* or *moderately sensitive* for prehistoric resources.

2) Historic sites

In the past, Division foresters have used original land taking plans, as well as direct observation, to identify the location of historic building foundations. In 1994, the Division contracted with Boston University to inventory historic sites on the Prescott Peninsula. This inventory identified a number of sites that were not on taking plans but were on 19th century town atlases. This project also improved the availability of information on the sites identified, by producing a data sheet and a map for each site. MDC plans to continue this project over the next several years in order to complete the inventory of historic sites at Quabbin. This information will be used by the MDC Chief Archaeologist when reviewing proposed silvicultural operations.

c. Harvesting Restrictions and Limitations

For those silvicultural operations planned for sites that have been classified as *highly* or *moderately sensitive for prehistoric resources*, restrictions are recommended on the time of year and the types of equipment and techniques used. By employing restrictions on harvesting operations that minimize ground disturbance, a compromise is achieved that allows the harvest to occur, while affording some protection to whatever archaeological resources may lie buried below the ground.

The following are types of restrictions/limitations that may be recommended for *highly sensitive* areas:

- the harvest should occur during the winter with frozen soil conditions;

- skidding should not be permitted;
- three wheeled feller-bunchers, such as the Morbell type, should not be employed;
- Fortech type feller-buncher-processors, with long reach and weight distributing tracks, should be used.

For those proposed operations in areas classified as *moderately sensitive,* one or more of the above restrictions may be recommended. As this is a relatively new review process, the details of appropriate restrictions are still being fine-tuned through close interactions between the Division foresters and the MDC Chief Archaeologist, including analysis of past management sites for potential impacts.

In some cases, particularly with large acreage sales, portions of a lot may satisfy some, or all of the site location criteria, while other portions satisfy none. Here some of the above harvesting restrictions may be recommended for the sensitive portion of the operation, but not apply in other portions. On rugged upland sites, or in previously-disturbed areas, that fail to meet the key criteria, no additional restrictions are placed on the operations.

2. Vegetation Management at Historic Sites

Recognizing the realities of existing, and likely future fiscal constraints, the Division has developed a strategy for preserving its historic resource base. The strategy is extremely modest in man-hours and cost, but it can have a lasting effect on the survival of historic archaeological sites in the Quabbin Watershed.

Vegetation, if left to grow unchecked in and around stone foundations, and other historic structures like dams, raceways, etc., will ultimately alter these archaeological features. The dislocation of foundation stones, and the spalling of cement caused by root activity are among the most immediate threats to some of these cultural resources. Should uncontrolled growth continue, in several cases the existing archaeological remains will be of little value and interest at the time that the Commonwealth is more solvent and prepared to undertake protective management once again.

Accordingly, a limited and selective management program to control vegetation growth in and around archaeological sites and historic buildings and structures is recommended. This same limited program has been employed on historic sites in the MDC Reservations & Historic Sites Division.

As a general site stabilization and preservation technique, vegetation management will entail:

- Removal of most small to medium sized brush, saplings, and trees from on, and within archaeological features i.e., cellar holes and their foundation walls; channelized stream beds; mill dams; and historic buildings.
- Removal shall be by cutting as close to the ground as feasible. Vegetation should not be pulled, or otherwise dislodged in a manner that would affect root systems.
- While manual removal may often be the best technique, in some cases where the terrain is sufficiently level and stable, the Fortech type feller-buncher may be appropriate. This machine

has a long reach that limits the need to bring equipment too close to the structure. It picks the tree up, thus there is no concern about the direction of the fall; and the tracks tend to distribute the machine's weight, thereby limiting compaction to buried deposits.

In most cases, Division staff should perform the vegetation management around historic sites. However, there may be private loggers/contractors who are well known to Division foresters, and who are particularly skilled and careful and could be allowed to undertake the work. At sites that are imminently threatened, and which otherwise fall within a proposed silvicultural operation, it may be prudent to allow the private contractor to perform the selective cutting around historic sites. Contracts could include clauses that direct the logger to take extra care and precautions around cellar holes/foundations etc. Vegetation management will in most cases require periodic and cyclical treatment depending on the nature of the growth, the condition, and significance of a specific site.

3. Long Range Cultural Resource Management Initiatives

The following is a list of important initiatives that should be undertaken when funds and staffing are available:

- Inventory historic sites. Identify by age, owner, activities, buildings. This data has been compiled for the 12,000 acre Prescott Peninsula and will be used to help list priorities for vegetation management efforts and improve the review of silvicultural operations. Future inventories will cover the remaining MDC lands at Quabbin.

- Enter known prehistoric sites into the GIS mapping system.

- Map areas sensitive for prehistoric sites based on site location criteria and enter into GIS.

- Conduct archaeological sampling of Red Pine Plantations, which were primarily planted on previously cultivated land, to determine the nature of sub-surface disturbance and survival factor for prehistoric sites.

- Nominate Dana Center to the *National Register of Historic Places.*

- Develop educational signage and displays on Native American landuse of the region. (Note: The Avery Collection, a small but informative artifact collection, could easily be incorporated into an exhibit).

- Encourage local universities to conduct *archaeological field schools* on watershed lands to further test and refine site location criteria.

E. Focusing Management Objectives: Cumulative Sub-basin Analysis

The Division's watershed management, forest management, and wildlife management goals outlined in Section IV specify the type of general watershed cover conditions the Division will strive to achieve. These goals are based on MDC's legislative mandates, previous MDC experience in watershed management, careful study of present conditions, extensive review of relevant research and literature, and consultation with experts in the field. However, within the watersheds at Quabbin, Ware River, Wachusett, and Sudbury, forest conditions, the amount of private lands and the uses of those lands vary greatly. In order to rationally list specific priorities for each watershed, the Division will broadly examine the conditions and relative importance of each drainage basin on the watershed, with regard to water quality and supply. For example, the 95,800 acres of land and water upgradient from the Quabbin Reservoir can be divided into approximately 100 small basins, averaging 950 acres in size. The technique of looking at the cumulative set of impacts occurring within a water supply and examining the ability of a watershed to withstand those impacts is an emerging technique within the water supply management community. This analysis is especially useful in designating areas where the "primary use" of water supply protection should take precedence, and areas where limited "secondary uses" could be allowed to varying degrees.

The Division will use this type of analysis to make the following types of decisions:

- the general location of forest management activities conducted to assist in the "Primary Use" of the watershed for water supply (given management priorities by forest type, susceptibility to disturbance, forest condition, basin location relative to water supply aqueducts, and condition of non-MDC lands in the basin).

- the location of future land acquisition purchases.

- the location of wildlife impact management activities.

- the location and extent of "Secondary Uses" (non-water supply land uses) on MDC lands. Secondary Uses include all activities or land uses that may result in less than optimal water quality protection - even if only on a very small acreage. Secondary uses include recreation, site development for administrative purposes, creation or maintenance of views, wildlife habitat management operations, agricultural uses, forest management for revenue generation, and natural area management.

At Quabbin. the process will revolve around the evaluation of the relative importance for water supply protection of each of the approximately 100 basins within the reservoir watershed using these general criteria:

- proximity to reservoirs and intakes,
- sensitivity of basin to water quality degradation (soils, slopes, wetlands, etc.),
- percentage and condition of forested MDC lands within a basin,
- development threat on private lands within the basin.

Basins rated as most important to water supply protection would be the highest priority areas for forest management, land acquisition, and wildlife impact management programs, as needed. Secondary uses would be discouraged on higher priority basins. High priority basins can be described

intuitively as those close to aqueduct intakes and sensitive to water quality degradation (either through high threat or low natural ability to absorb pollutants).

Basins rated as compatible for limited secondary uses would intuitively be those far from intakes, less sensitive to water quality degradation, and well-buffered from impacts. This buffering might include deep soils or the presence of wetlands, which help buffer possible negative impacts from these secondary uses.

Due to the large amount of information that needs to be processed and rated to utilize this evaluation process, the Division will use a decision-making computer program and its computer mapping system (Geographical Information System) in order to more objectively and accurately rank the Quabbin basins. The Division has chosen a software program that utilizes the Analytical Hierarchy Process (AHP), a method by which each variable is given the appropriate weight(s) in making large and complex decisions (Expert Choice, Inc. 1992). "Expert Choice" takes the complicated AHP and simplifies it for management decisions of various types. Quabbin staff in the areas of environmental quality and natural resources reviewed this decision-making process and refined the list of useful and measurable variables to utilize in this model to a manageable number (see list below). Utilizing "Expert Choice" Division staff will rank the relative importance of each of these variables.

List of Variables for Expert Choice Analysis:

- Ownership
- Erodibility
  - slope
  - cover
  - road density and type
  - soils
  - wetlands
  - beaver activity
  - stream density
- Location Relative to Intakes

As of the writing of this plan, Division staff have applied a version of this model to two basins as a test run. The results of this initial test run show that basins near aqueducts are inherently important, but that other factors such as soil, slope, cover, etc. produced results not predicted by intuition alone. The Division is also examining the use of the "Drainage Area Zonation" method that is used to improve the accuracy of ratings for the value of parameters within each basin such as steep slopes and wetlands (Hakanson et al. 1990; Nilsson and Hakanson 1992). For example, two basins may both have 15% in steep slopes but the basin with steep slopes adjacent to streams and the reservoir would be rated as a less stable basin. In addition, the parameter of "location relative to intakes" will utilize information on sensitive areas from the reservoir model being developed by the University of Massachusetts beginning in 1994. Due to the complexity of this project, it will be phased in gradually during this management period.

F. Quabbin Park Management Plan Outline

Quabbin Park is the 3,100 acre section of MDC Quabbin lands roughly between Winsor Dam and Goodnough Dike. This area is of particular interest because it receives much more visitor use than all other MDC Quabbin lands combined, contains the largest area of open fields directly adjacent to the reservoir, and is directly adjacent to the Chicopee Valley Aqueduct. Usage is heavy here because there are several miles of paved roads, scenic vistas, picnic sites, an observation tower, numerous pull-offs and parking lots, and over 100 acres of mowed fields for passive recreation. The Division operates a visitor center here as a way to educate the public about Quabbin and the special use restrictions that apply. MDC maintains the two large earthen dams in Quabbin Park, which hold back the reservoir, and also operates a cemetery containing the graves of former Swift River Valley residents. The Division has also begun using electric fencing to deal with the deer impact problem in this area.

Quabbin Park requires a high level of staffing for trash pick up, mowing, visitor education, and the maintenance of buildings, facilities, dams, paved roads, deer fences, vistas, trails, and picnic sites. However, because much of Quabbin Park does not drain into the reservoir, many of these activities draw resources away from watershed protection. A plan is needed for the park in order to focus resources on protecting the reservoir area adjacent to the park and to reduce the resources utilized on activities that do not protect the reservoir. The education of the public and the demonstration of appropriate watershed practices within the park will also be a goal of the plan. This plan will be completed under a separate cover and will include the following topics:

- Purpose of Plan

- Evaluation of Current Situation: Evaluation of numbers of users, types of activities and seasonality of use. Evaluation of current management requirements for cemetery and park.

- Goals of Plan: Protection of water quality from non-point discharges and public access. Education of the public and demonstration of watershed management activities. Protection of natural and cultural resources. Efficient use of limited staffing and equipment resources.

- Planning by Activity: Management of public access (picnicking, biking, auto touring, hiking, group use, etc.). Management of facilities and resources (forest, animal control - deer, beaver, rodents in dam, historic sites, fields, roads, and signs). Public education activities (visitor center, programs and walks, informational signs and brochures, demonstration areas, etc.).

- Planning by Location: Management of reservoir watershed, especially shoreline and intake areas versus off-watershed lands. Site specific access control measures for vehicles, bicycles, and pedestrians. Special Quabbin Park Cemetery management. Site specific recommendations (mowed fields, Hanks Meadow, spillway channel, Enfield Lookout, Quabbin Hill, Winsor Dam, Goodnough Dike, Blue Meadow Road, etc.).

- Public Input: Issues from the using public, Chicopee Valley Aqueduct users, etc.

VI. Research

A. Introduction

The Division currently has numerous ongoing monitoring, inventory, and research projects underway, including:

- a study of the interaction of silviculture, ferns, and deer browsing on the Prescott Peninsula;
- a study comparing the impact upon soil and regeneration of various logging systems;
- an inventory of the Quabbin forest each ten years with the remeasurement of its more than 300 permanent 1/5 acre plots;
- monitoring of regeneration inside the deer exclosures and regeneration plots around the watershed. One fence on Prescott Peninsula that has been up for seven years was recently removed on one half of the 25 acres enclosed in order to compare the development of the protected and unprotected regeneration;
- inventories comparing forest regeneration in areas with different light levels and deer browsing pressure;
- various wildlife population surveys;
- annual surveys of vernal ponds at Quabbin, with over 15,000 acres surveyed to date. Interpretation of recently-acquired aerial orthophotos and infrared photography will allow MDC to put additional inventory information on its geographical information system.

Over the past ten years, more than 50 projects have been undertaken on the Reservation. A number of professional publications have been generated by this research in a wide range of topics including hydrogeology, forestry, and wildlife. For the past several years, the Division has required researchers outside of MDC to complete a process that includes annual reports, in order to gain permit renewal.

Results of professional watershed research done in the Quabbin area (see Supporting Appendices) provides a considerable baseline of information in the area of hydrogeology and several suggestions for future research. However, in order to have more direct involvement in professional research that will assist in watershed management decision-making, the Division is developing a research plan and budget to support watershed-related studies.

The research plan will include a list of research projects that the Division would like to see conducted on its watershed lands. This list will be circulated to local academic institutions in hopes of stimulating interest in some of the projects. Further, establishment of a research budget would not only provide a means of financial support for some of these projects, but also serve as a concrete way to link the resources of the various departments of the University of Massachusetts and Harvard University, both of which have a great interest in future research at Quabbin. In this way, the Division would foster a cooperative program of research aimed at answering questions that will assist MDC watershed management decision-making.

One way to focus a cooperative research effort, is to collect information with the intent of creating a comprehensive computer model to help decision-making. The Division has already cooperated on a project that resulted in a computer model of lands susceptible to future hurricane damage (Ottenheimer 1992). Hemond et al. (1987) modified the BROOK small watershed hydrological model (see Miller et al. 1986) to model water chemistry at Bickford Pond watershed at the Ware River. In addition, the Division plans to utilize GIS to create a model to set priorities regarding the importance of sub-basins within the Quabbin in order to assist in forest management and land acquisitions decision-making. A graduate level class at the University of Massachusetts during the fall of 1992 examined the need for research at Quabbin. They recommended that BROOK be used to evaluate water yields under various management scenarios and that a watershed water quality model be developed (Mather 1993). While these efforts are useful, they are not comprehensive in scope.

A comprehensive model would be useful for improving the understanding of various processes at Quabbin and would also be helpful in predicting the outcome of various management approaches. This type of model would also be useful in generalizing the results of research on small areas to larger areas and optimizing the value of a management approach given variations in a watershed (Cosby et al. 1985; Hall and Day 1977). Two types of models exist: 1) empirical, analytical or "black box" models that predict future input/outputs based on the mathematical relationship of past input/outputs, and 2) process-oriented or simulation models that emulate actual processes (Cosby et al. 1985: Hall and Day 1977). These authors strongly recommend process-oriented models and ones that are not overly complex.

However, even a comprehensive model is not a panacea and will be limited by the quality of inputs. Such a model should be seen as a tool along with observation, field experience, adaptive management experiments, inventory, review of other studies, and on-site research (Hall and Day 1977). In addition, models can oversimplify complex natural systems or can be too difficult to apply if constructed with too much detail (Mather 1993).

In order to efficiently expend limited MDC funds, research money will be used to complete the following three projects:

1. *Hydrological Model Evaluation*: The purpose of this project is to evaluate existing biogeochemical hydrological models in relation to MDC watershed land management needs at Quabbin. Utilizing an interdisciplinary team, the strengths and weaknesses of the most applicable models will be evaluated given Quabbin's unique characteristics. One model, or a combination of compatible models, will be recommended for implementation. The feasibility of implementing the model at Quabbin (including cost, technical difficulty and usefulness of results) will be examined. The selected model should include water quantity and chemistry and include variation in parameters such as soils, surficial geology, wetlands, and forest type and density. The team will also evaluate the type of information that still needs to be collected in order to accurately run this model. For example, several researchers believe surficial geology and soil depth are critical parameters to map in order to have accurate hydrologic models (Goldstein et al. 1985; Newton 1987 as cited in Nilsson and Hakanson 1992; Yuretich, 1992). Other researchers believe that sampling of forest litter chemical composition is an efficient way to accurately model nutrient cycles in forests (Aber et al. 1989). In addition, research may be needed in order to accurately assess the importance of wetlands (especially different types and locations of wetlands within basins). The research of Suurballe (1992), Hemond et al. (1987), Rittmaster and Shanely (1990), and Shanley (1993, pers. comm.) should be reviewed. Additional research may be needed in order to accurately predict water yield changes due to various

forest management approaches (for example, there was a large difference in water yield increases from experiments at Dickey Brook vs. experiments at Cadwell Creek).

2. *Monitoring of Logging*: The purpose of this project is to establish a standard approach to measuring compliance with MDC's policy of no measurable impact upon stream water quality from forest management activities. Two streams will be monitored to correlate short-term water quality changes to active logging conducted on MDC lands within MDC constraints. Monitoring will involve upstream and downstream sampling before two planned operations, during active logging, and following the completion of the operations. The study will focus on storm event testing (using automatic water samplers) to focus the study on worst case situations. Parameters will include turbidity, suspended solids, total particulates, temperature, total and fecal coliform, and nutrients. Based on this field work, specific recommendations will be made outlining a low cost, statistically valid method of monitoring logging operations on a more wide-scale basis. Recommendations regarding adjustments in current MDC Best Management Practices would be made if necessary.

3. *Beaver Impacts on Water Quality*: The 1991 Watershed Protection Plan for Quabbin Reservoir (MDC/MWRA 1991) called for "a study on the impact of beaver dams" to determine the water quality and public health threat posed by their presence and removal. To address this concern, the location, size and status of beaver dams and flows at Quabbin will be inventoried. In addition, information on the condition of specific beaver dams and flowages will be assessed for a limited area in proximity to the two aqueduct intakes at Quabbin. Within the intake areas, beaver sites will be categorized according to dam stability, dam location within the stream basin, hydrology of the basin (size, steepness, "flashiness", etc.) and other relevant parameters. Baseline water quality data (including turbidity, nutrients, organic carbon, *Cryptosporidium* and *Giardia*) will be collected above, in, and below a representative sample of beaver flows adjacent to intakes and at sites that reflect the main categories of beaver sites. Sampling will include routine and storm sampling. The data from this study will be coordinated with the reservoir modeling project to be completed by the University of Massachusetts beginning in 1994. Of special concern should be the tracking of movement of parasites and total organic carbon from tributaries, through the reservoir, to the two intakes (especially the CVA).

Two of the above three projects will require more than one year to complete and MDC will commit funds in future fiscal years to complete these projects. Priorities for additional forestry and wildlife research projects are listed below. These projects will be begun by Division staff or a combination of Division and University personnel, with future year's research budgets. These projects reflect the priorities of this plan in that projects that assist in the restoration of forest regeneration receive the highest priority.

B. Forest Research

1. *Recovery of Quabbin Understory*: There are numerous small projects that need to be completed regarding the recovery of the Reservation understory. The Division needs to develop a predictive model for herbaceous competition, especially for hay-scented ferns. This would involve mapping existing areas where ferns are a serious obstacle to regeneration and testing (including analysis of variance) for the most important variables (soil nutrients, soil moisture, overstory type and condition, past land use). The Division needs to determine the effectiveness and cost of various scarification methods for reducing fern competition, including mechanical scarification and burning.

The Division should test (via soil nutrient testing) the hypothesis that ferns are mostly a problem in past agricultural land, due to residual nitrogen accumulations. The effects of soil moisture on the productivity of ferns should be studied. The impact of liming areas (there is a theory that ferns grow best at low pH's) should be tested to see the effect at various intensities on fern growth. The use of short tree tubes as a method of getting planted stock to grow up through heavy ferns should be tested. The progression of normal forest succession in heavy fern areas should be studied following the reduction of deer browse pressure, to begin to get a sense of how long recovery of regeneration will take without intervention.

2. *Impact of Controlled Burning on Forest Regeneration*: Controlled burning is an efficient and effective method for keeping fields open, and has the added benefit of keeping MDC fire-fighting skills honed. Burning has been shown to stimulate regeneration of certain species. Controlled burning could be tested to see if it measurably rejuvenates and stimulates forests with long term deer browsing impacts.

3. *Analysis of Optimal Riparian Vegetation*: While the opportunity to shift species composition on the watersheds is limited by site, seed, overstory conditions, etc., it would be valuable to complete an investigative literature review to determine the water quality benefits/detriments associated with each of the common tree/shrub species. While species selection for an entire watershed should be based primarily on site suitability and species stability, in areas directly adjacent to tributaries and reservoir shorelines, a species' direct impact on water quality may have a measurable benefit. One result of this would be to generate a model of the ideal riparian forest for various sites. Models developed recently to quantify the buffering effects of riparian forest should be examined for applicability to Quabbin forests.

4. *Evaluation of Quabbin Access Roads*: Given that roads are the most likely source of pollution/sedimentation problems on MDC lands, a systematic evaluation of the Quabbin roads system would be valuable. At present, road conditions are monitored on an ad hoc basis by both forestry and environmental quality staff and erosion control improvements are prioritized accordingly. This project would include a watershed-wide mapping of road conditions, to identify trouble spots. An additional project would involve testing for sediment transport during storm events from steep sections of gravel road, the areas most vulnerable to erosion. Part of this project would involve locating the most appropriate model for sizing culverts (see Wandle, n.d.) and utilizing GIS to routinely size culverts and design roads that will withstand 50 year storms.

5. *Forest Litter Sampling*: Researchers have developed models that predict the products of litter decomposition from a chemical analysis of litter (Aber et al. 1990 and Curie and Aber 1994). This information could be used in assessing nutrient cycling in the Quabbin forest and could improve the accuracy of a watershed hydrological model. Information on the relationship between forest cover, land use history, and litter chemistry could be obtained. Forest litter would be initially inventoried to map basic physical characteristics of forest litter at Quabbin and a representative sampling of litter chemistry would be obtained for major categories.

6. *Plant Inventory*: While the Division has completed regular forest inventory through its Continuous Forest Inventory (CFI) system, this gives only qualitative information on non-tree species. This expanded inventory, on selected CFI plots representing a variety of sites, would allow a complete listing of the more common non-tree species by site.

7. *Rare Plant Surveys*: The Division should contract with qualified botanists (working in conjunction with the Mass. Natural Heritage and Endangered Species Program staff) to have an inventory of rare and uncommon plants completed on the watershed. This would involve investigation of sites with the highest potential for containing rare and uncommon species. This study would also include recommendations on avoiding impact to rare plant communities.

8. *Monitoring of Conditions on Managed Areas and Areas Where Silviculture Does Not Occur*: The 1991 Quabbin Reservation White-Tailed Deer Impact Management Plan outlined an extensive research project to evaluate differences in a wide range of parameters (including water quality and flora and fauna) between areas with and without forest management and deer management. The main purpose of this research was to examine long term differences in conditions resulting from various approaches to forest and wildlife management. The Division hoped that there would be interest in funding this project from outside MDC but to date, none has surfaced.

It has been suggested that the Division could gain this type of information through coordination of its current water sampling and continuous forest inventory programs. The thought was that by correlating cover type and management approach for areas upstream of water sampling sites, a conclusion could be drawn as to the optimal cover for maximizing water quality. However, a much more complex approach would be necessary for a study of this type to produce results with any meaning. For example, cover conditions are only one of the factors affecting the quality of water found at the various sampling sites; other factors include geology, soils, topography, aspect, and inputs from non-MDC lands. Unless parameters are isolated, it is impossible to determine the specific causes of differences in water quality. In addition, the long-term benefits of wildlife and forest management programs in maintaining forest integrity despite major natural disturbances may not be apparent in a short-term study.

In order to produce useful results, this study should compare three watershed basins completely within MDC boundaries with similar topography, aspect, soils, and surficial deposits. These basins should include one on which forest/wildlife management had not been active for many decades, one on which management has been recently initiated and one on which management has achieved MDC's objectives. Within each watershed, water quality and quantity should be correlated to soil physical and chemical properties and the condition of flora (including forest growth, species/size composition and leaf area index measurements) and fauna. Key wildlife habitat differences should be measured, such as the amount of standing and down dead wood in each of the study areas. In order to be continued over a long time period, the study should be set up so that data can be collected with minimal effort. The information generated from the development of a watershed model (see project #1 above) should be used in selecting watersheds to study. The Division should consult with Harvard Forest personnel to evaluate the usefulness of conducting simulated hurricane impacts on limited areas (as has been done at Harvard Forest) in order to measure response of different systems to these impacts.

9. *Detailed Analysis of CFI Plot Data*: The more than 300 CFI plots that have been monitored for 30 years contain a wealth of data about the changes in the Quabbin forest. Computerization of plot measurements from 1965 and 1970 would allow the Division to detail trends in forest growth and decline.

10. *Analysis of Dead/Down Woody Material on Managed/Undisturbed Areas*: Dead standing and down woody material, including snags, logs, limbs, and stumps, have clear wildlife value and may also serve important functions in erosion control and nutrient cycling (Hunter 1990). There is

speculation that the managed forest contains less of this material than one that is undisturbed. The Division should conduct inventories to investigate the significance of these differences.

11. *Geographical Information System (GIS) Projects*: MDC recently acquired the capability to utilize the state GIS at Quabbin. MDC has also acquired color infrared aerial photos and digitally-corrected black and white aerial orthophotos as part of the Wetlands Conservancy Project. Additional GISwork is needed in the areas of forest typing and generating bedrock and surficial geology maps.

GIS systems will be used to develop models in the areas of cultural resources management, wildlife habitat assessment, and logging difficulty rating. For cultural resources, the Division will build on work done by Berger Associates at Quabbin in 1986 and by Thomas Mahlstedt, MDC Chief Archaeologist at MDC's Neponset River holdings. This model will use known characteristics of pre-historic sites at Quabbin to delineate areas of potential archaeological sites. The wildlife model will incorporate the species-habitat relationships described in DeGraaf and Richard (1987) to model generalized impacts of MDC long-range forest management upon wildlife species. The logging difficulty rating will build on a model developed by Salem State University for MDC in 1989 that rates the environmental sensitivity of areas marked for logging, so that loggers would have a more exact understanding of the special actions required to protect the natural and cultural resources on the lot.

12. *Analysis of land use history at Quabbin*: The land use history for the 250+ years since settlement in the Quabbin region has a great deal of significance to the present forest composition and ecology (Foster 1992b; Foster et al. 1992; and Motzkin et al. 1994). This information will be very important when making decisions on the suitability of various species/site combinations. Utilizing taking plans and deeds from the purchase of MDC lands, Division silvicultural records, and field sampling at representative sites, useful information regarding the changes and impacts of the past 250 years of land use can be obtained.

13. *Watershed Management Symposium*: Symposia of watershed managers in the northeast have occurred at the University of Massachusetts in 1965 and at S.U.N.Y., Syracuse, NY in 1975. These conferences were extremely useful in sharing emerging ideas on watershed management. MDC should consider co-sponsoring a watershed management conference for the 1990's with the University of Massachusetts, which would utilize the Quabbin watershed as a case study and tour site.

C. Wildlife Research

A variety of wildlife research and monitoring activities have been conducted on Quabbin in recent years, but much more remains to be studied. The following research projects are designed to provide the technical data necessary to support management decisions in the wildlife programs on MDC Quabbin lands. Several of the studies described in the above section also contain wildlife components.

1. *Deer Population Surveys*: The Division has utilized "Line Transect Counts" to obtain estimates of deer population density on Quabbin Reservation prior to conducting deer herd reductions. These estimates provided valuable information and assisted in designing reduction programs, as well as measuring the effectiveness of those programs. The Division conducted deer transect counts in the Pelham area for three years, as part of the deer reduction effort there. For the past eight years, the U.S. Forest Service has conducted deer transect counts on Prescott Peninsula in conjunction with their

ongoing studies. Division personnel have assisted in those counts, and the results have been used in planning and evaluating the recent deer hunt at Prescott. However, as deer densities are significantly reduced, the transect method becomes less useful, as the number of observations greatly declines. The Division will continue to assist in counts conducted by the U.S. Forest Service, but will also explore other options for gathering deer population information. In 1994, the Division began testing a thermal infrared scanning technique for monitoring deer densities. This method appears to be an efficient method for gaining deer population data, given lower deer densities.

2. *Biological Surveys and Inventories*: To minimize negative impacts and maximize positive benefits on wildlife resources on the watersheds, all logging, gravel removal and other land management operations planned by the Division are reviewed by the wildlife biologist. Since it is impossible to physically check the hundreds of acres proposed for management each year, Division staff rely on file records of known occurrences of significant wildlife habitats. Although new information is added as it becomes available (e.g., from the vernal pool surveys conducted in recent years), the database on such occurrences is not complete. Biological surveys conducted by qualified individuals can provide additional information that will enhance MDC efforts to protect and enhance these resources during management activities. Such information can also be incorporated into the MDC GIS to further facilitate its access and usefulness.

3. *Vernal Pool Surveys*: Surveys of vernal pool locations and wildlife use have been conducted on 15,000 acres of MDC lands at Quabbin since 1987. These surveys have provided useful information that has already been incorporated into management decisions, and have also documented the occurrence of several special concern species on the watershed. The Division will continue with spring surveys to locate these important wildlife habitats, and will also work with the Massachusetts Natural Heritage and Endangered Species Program, and other agencies and institutions, to obtain further knowledge and understanding of these habitats. In order to supplement these surveys, the Division will utilize the interpretation of recently-acquired aerial orthophotos and infrared photography to put additional inventory information on its geographical information system.

4. *Routine Monitoring Activities*: Routine monitoring and population survey activities conducted in recent years will continue during this management period. These include annual surveys of beaver activity on Prescott Peninsula, breeding bird censuses conducted on Prescott and in Petersham, Canada Goose surveys conducted each September, deer thermal infrared scanning or spotlight counts, and monitoring of Common Loon nesting activity on the Reservoir. Other monitoring activities (e.g., coyote surveys, grouse drumming counts) have been conducted periodically in the past, and will continue if and when resources permit.

VII. Public Involvement

A. Public Input in Formulating Watershed Management Plans

Public input represents an important part of the Division's management planning process. This input is provided in several ways, including through the Quabbin Watershed Advisory Committee, local experts in resource management, and the general public. The goals of the Division's public input process are:

- to understand the broad range of public issues and concerns regarding forest and wildlife management at the Division's watersheds so that the Division can better integrate the concerns of the public into protection strategies for maintaining watershed integrity;

- to improve the understanding of the technical aspects of forest and wildlife management on the Division's watersheds and to generate creative program ideas;

- to educate the public regarding the purposes and goals of the Division with regard to its watershed management program in order that the public will better understand the program chosen in managing the forest and wildlife resources at Quabbin; and

- to gain support for the implementation of the watershed management program selected by the Division so that it may be implemented smoothly.

Throughout the public input process, the Division has stressed that its primary legislative mandate is the delivery of sufficient quantities of pure water to present and future generations of water users of the system. This mandate is much narrower than that of most public land managing agencies. Therefore, it is important that the public understand that management alternatives that do not adequately support the Division's primary mandate will not be considered viable. While the Division considers secondary values of its watershed such as passive recreation, environmental research, natural areas, and wildlife management, these values will only be encouraged and enhanced where they do not impair the primary mandate of the Division. Occasional conflicts may arise between state and federal laws (e.g. rare and endangered species, wetlands, and historic sites) and prudent watershed management. These conflicts will be examined on a case by case basis to ensure that the requirements of laws protecting non-water supply resources are met while still protecting the water supply.

Chapter 372, Acts of 1984 states that the Division of Watershed Management shall prepare watershed management plans each five years that provide for forestry, water yield enhancement, and recreation. The legislation further states that these plans shall be prepared with the participation of the appropriate watershed advisory committee and a professional forester. Two committees, the Quabbin Watershed Advisory Committee (for Quabbin and Ware River) and the Watershed System Advisory Committee (for Wachusett and Sudbury), were also formed by this legislation, which also requires that public hearings be held on these watershed management plans.

The DWM began the process of developing this management plan by working with the Quabbin Watershed Advisory Committee (QWAC). However, due to the technical nature of this plan, input was also sought from appropriate watershed management, forest, and wildlife experts outside of MDC to improve the technical presentations in this plan. To facilitate early input and ideas, the Division distributed first drafts of each section, as they were completed, to QWAC members. In addition, the Division held a one day discussion with hydrology and forest ecology experts from

Harvard Forest, University of Massachusetts and S.U.N.Y College of Environmental Sciences and Forestry to consider the general approach MDC had taken with regard to forest watershed management in this plan. The plan was also reviewed in May, 1994 at a Watershed Workshop to which more than 60 representatives of various environmental organizations and interest groups were invited. Issues raised at this workshop are summarized in the Supporting Appendices.

The general public has also been involved in reviewing and commenting on the development of this plan throughout the process. Copies of all plan drafts were widely distributed, to local libraries, academic institutions, other state agencies, and to individuals and groups requesting copies. The Division also made a presentation about the plan to the general public at the Quabbin Visitor Center. Finally, public input was also received on the final draft at, and following, a public hearing on the plan held on July 27, 1994. Some reviewers spend many hours reading and commenting on each draft of the plan, and provided many useful comments and suggestions. In other cases, reviewers made requests that the Division did not consider to be compatible with its main mandates regarding water quality protection. Still, such comments were useful in identifying the range of opinions and public desires regarding the management of Quabbin lands. The comments received on the final draft of the plan, and at the July 1994 public hearing, along with the Division's responses to those comments, are presented below. Comments and responses on earlier drafts of the plan are summarized in the Supporting Appendices.

Comments on July 1, 1994 draft (NOTE: references to specific plan sections refer to the July 1, 1994 draft, not this current version):

1. (WSCAC letter 8/19/94) To complement MDC's annual review/workshop with the public, staff-guided visits to watershed management areas would be useful to prevent miscommunication.

The Division has an ongoing commitment to this type of public interaction, and has clarified this under the Public Involvement section of the plan. Division staff have conducted a wide variety of field tours for both general public and specific interest groups, but will work to focus at least one annual tour on outstanding management plan issues. In October 1994, a small group of WSCAC members was accompanied by MDC Natural Resources staff on a boat tour of shoreline plantations proposed for "non-harvest manipulations", a controversial and misunderstood plan proposal.

2. (WSCAC letter 8/19/94) The plan does not provide for the replacement of the oldest age class, the trees within the 1/3 of the forest that is essentially "unmanaged". How will this older third be replenished?

The plan is focused on the next 60 years and assumes that the oldest third of the forest will continue to survive and grow older during that time frame, without significant losses. As this oldest third reaches biological maturity and begins to decline, future foresters would designate the oldest trees from within the younger two-thirds as replacements for the dying trees. Furthermore, openings made by these dying trees would regenerate, thus substituting younger forest for the replacements that were left to grow. This approach would maintain the desired multi-layered structure, while shifting the physical location of the generally unmanaged one-third. The frequency of these shifts would be determined by the maximum attainable age of the oldest trees in an area. The younger two-thirds would still be treated every 20-30 years, to maintain the understory and midstory components of the forest.

3. (WSCAC letter 8/19/94) What methods will MDC use to conduct the more sophisticated inventory required to implement the proposed uneven-aged management approach?

The Division has drafted a manual of "Forest Inventory and Monitoring Procedures", which details the stand exam system of inventory and control that will be used. This system includes the collection of stand information, the comparison of this information to targets for structural and species composition of forest areas, and the development of marking guidelines for application by foresters during the preparation of timber harvesting lots. This manual will be distributed and discussed at the 1995 spring workshop on management plan progress.

4. (WSCAC letter 8/19/94) The plan focuses on the development of trees in the forest, but seems to consider shrubs primarily as a hindrance to be overcome, rather than a viable component of the watershed forest.

The plan does consider certain specific, highly competitive shrubs to be a hindrance both to the development of trees and to the general diversification of the forest understory. Chief amongst these are mountain laurel and Japanese barberry. Mountain laurel is a very common shrub on moist slopes in Massachusetts and is capable of overwhelming its habitat to the exclusion of other shrubs or trees. This is contrary to diversification goals, so that efforts will be made to control its spread and promote diverse shrub and tree understories. Japanese barberry is an imported, non-native species that is not commonly browsed and has therefore spread in areas where deer populations have been high. It is expected that deer reduction alone will bring diversity back to barberry-dominated understories. In general, the shrub component of the watershed forest has been greatly reduced or eliminated by heavy browsing, and its return is as welcome as the return of the tree component of the understory.

5. (WSCAC letter 8/19/94) "Research in the CFI plots monitors successful regeneration on milacre plots and extrapolates this to stems per acre based on counting up to a maximum of two stems of the required size, per plot. This drops out the information of the actual number of stems per plot and must therefore lead to an undercount for the full acre. This certainly biases the results."

In fact, the text of the plan states "regeneration inventory on CFI plots was conducted simply to determine the percentage of plots that were adequately regenerated, rather than to derive the mean stem density per acre by species", and the associated Figure shows the percent of all CFI regeneration plots that had at least one stem (representing at least 1000 stems per acre). No attempt was made or implied to use these particular regeneration plots to calculate the mean stems per acre. "Mean stems per acre" is calculated using annual regeneration transects (milacre plots every 200 feet along fixed lines). The CFI approach is useful in that it eliminates the bias associated with counting every stem in a milacre plot and extrapolating this to a mean value per acre; no milacre plot will ever retain more than one or two trees to maturity.

6. (WSCAC letter 8/19/94 #4) "Active management for selected wildlife species (p.83 of plan) should be restricted to limited research programs and closely supervised and documented. All secondary use areas should be off-watershed, unless careful analysis and public review of need and impacts has been done."

Secondary use areas will be identified using the procedure described in Section V.E. These areas can occur throughout the watershed, but only on drainages considered "less critical" for water quality protection. Active wildlife management on these areas will occur in appropriate habitats, and initially will be geared towards species identified by the Massachusetts Partners in Flight committee.

7. (WSCAC letter 8/19/94) "Animals and plants of the watershed should be allowed to remain in some reasonable balance, except when intakes or safety-related infrastructure are threatened."

MDC policy regarding wildlife activity on its watershed lands calls for co-existence, except in specific situations where watershed infrastructure, public safety or water quality are at risk. A statement has been added to the plan (Section V.C.3.) clarifying this policy.

8. (WSCAC letter 8/19/94) "Plan makes no mention of the impact of past forestry practices on the present deer population. Won't some of the proposed practices encourage deer browse and perpetuate the deer population problem?"

This issue (i.e., forest management impacts on the deer herd) was thoroughly discussed in the various documents issued in conjunction with the 1991 Deer Impact Management Plan. The basic problem at Quabbin had been that deer populations were controlled by food supply (i.e., the deer herd expanded to the point where they were consuming most of the tree regeneration). The bottom line is that in achieving MDC's watershed cover goals, it is inevitable that additional tree regeneration will be created on the Reservation, and this will improve deer habitat. However, the long-term benefits to water quality protection that will result from implementing this land management plan will far outweigh the consequences of this deer habitat improvement (i.e., the need for some form of continued population or impact control).

9. (WSCAC letter 8/19/94, attachment) [Re-statement of various concerns expressed in an earlier correspondence regarding the presumed impacts of beaver activity, a presumption of "innocence until proven guilty", the lack of a demonstrated occurrence of *Giardia* in Quabbin water, etc.]

These issues were directly addressed in the "Summary of Key Public Comments" - Section VII.D.; comments #16-25 - in the July 1, 1994 draft of the plan. MDC's policy regarding beaver activity calls for a site-specific, case-by-case assessment of beaver problem situations before any mitigation measures are considered or implemented. In cases where no detrimental impacts are obvious, beaver are allowed to occupy those sites.

10. (WSCAC letter 8/19/94, attachment) [Re-statement of various concerns expressed in an earlier correspondence regarding the lack of pre-hunt deer population information and the need for a complete review and accounting of the deerhunt program, and clear proposals for future hunts.]

These issues were directly addressed in Section VII.D. of the plan. A complete review of the deer hunting program will be conducted in 1997. In addition, the following responses are offered: The success of the first years of deer hunting at Quabbin demonstrated that deer herd reduction was proceeding at a faster rate than initially expected, and this allowed expansion of the program to other areas sooner than anticipated. Consequently, there was insufficient lead time to collect meaningful

population data in all new hunt areas. Further, as demonstrated during post-hunt population counts in Pelham, the substantial herd reduction during the first year of hunting there resulted in an inadequate number of sightings to assure statistical validity of the resulting population estimate. Since harvest data provides an efficient, easily-obtainable alternative means of population analysis, a decision was made to focus data collection efforts on the harvest itself. Presently, computer modelling is used to reconstruct pre-hunt population size and structure, and to predict future population characteristics. In addition, high-tech infrared scanners were used in 1994 to conduct more accurate "spotlight" counts in several hunt areas.

11. (Ruhf letter 8/18/94) "References to deer impact control program should not imply that there is necessarily an active control program for the next 10 years."

Wording in plan has been changed to clarify that a major review and evaluation of the current deer impact management program will be conducted in 1997.

12. (Bennett letter 8/24/94) "The contention that Alternative #2 provides the greatest amount of wildlife diversity is...a specious argument. True wildlife diversity...would be enhanced by allowing and maintaining a diversity of habitat types, not by increasing the predominance of one forest type."

The Plan does not suggest that wildlife diversity would be greatest with Alternative #2. In fact, it says that it would be greatest under Alternative #1, which would provide the greatest diversity of habitat types.

13. (Public hearing 7/27/94; comment from several people) "Alternative #3 is not treated fairly in the plan. It appears to be a "strawman", used simply to further justify MDC's selection of Alternative #2."

Alternative #3, as well as the whole section on the selection of a management approach (Section V.B.2.), has been re-written.

B. Regular Revisions to the Quabbin Land Management Plan

Watershed management is a developing science. In order to accommodate new findings in the field, and to adapt management policies based on local experience, MDC will revise and update this plan on an annual basis. The Division will hold a public workshop each spring in order to update government officials, environmental organizations, and the general public regarding the watershed land management activities conducted over the past fiscal year. In addition, the Division will outline planned watershed land management activities for the coming fiscal year. At that time relevant ongoing Quabbin research, new professional literature, and comments from the general public can be incorporated into the next year's program.

On an ongoing basis, the Division will place specific descriptions of active forest management operations in a notebook in the Quabbin Visitor Center so that visitors can learn about and make

comments on current management work. In addition, Division staff will conduct at least one annual field visit to management areas specifically to clarify program elements that seem misunderstood or controversial. This field trip will be in addition to the wide variety of tours that MDC Natural Resources staff currently conduct for both general public and specific interest groups.

C. Science and Technical Advisory Committee

In the past, MDC has formed special task forces and advisory committees on issues where specific technical expertise was necessary. For example, in assessing the impact of deer browsing, the Division assembled a panel of natural resource experts and in drafting best management practices for its watershed management crew, MDC assembled a panel of foresters and timber harvesters. In order to update and improve its plan each year and to deal with many of the future issues identified in this plan, MDC will form a special Science and Technical Advisory Committee to supplement the input of the Quabbin Watershed Advisory Committee (QWAC). This committee will have representation from QWAC (members with technical expertise in the natural resources or watershed management areas) in order to maintain communication between these two committees. Other members will be from the University of Massachusetts and Harvard University (institutions with natural resource and hydrological expertise and involved in research at Quabbin), state and federal natural resource and water supply management agencies, and conservation organizations with special technical expertise in natural resources, watershed and water quality study and management. The core group of this committee will be composed of persons with professional experience in environmental research.

The Science and Technical Advisory Committee will review annual changes in the Land Management Plan and advise MDC in the development and implementation of a scientific research program at Quabbin. In this way, the committee will function as the "bridge" between professional environmental research and management. In addition to general advice, the committee will assist in the following special issues raised in this plan: setting of research priorities, development of standards for research quality assurance and control, sub-basin modeling, decisions with regard to future designations of lands with special management restrictions, and management considerations for the Pottapaug Natural Area. In conjunction with the project to investigate the appropriate watershed model for Quabbin (described in the previous section), the Science and Technical Advisory Committee could organize and convene a meeting of experienced research forest hydrologists (with funding provided by MDC), in order to gain specific input on Quabbin hydrologic modeling issues.

VIII. List of Contents of Supporting Appendices

NOTE: The "Supporting Appendices" document is separate from this main document. The list below is attached simply to display the contents of that document.

History of the Quabbin Forest
Literature Review
Land Acquisition
Fire Policy
Roads and Gates
Compartment Descriptions and Maps
Project Description Form
Public Comments on Plan Drafts and MDC Responses

IX. Literature Cited

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GLOSSARY OF TERMS

Listed in alphabetical order below are terms and definitions that the MDC uses throughout various watershed land management plans. Specific sources of definitions are shown in parenthesis, where applicable.

age class: (from Society of American Foresters, 1971. Terminology of forest science, technology, practice, and products.) one of the intervals, commonly 10 years, into which the age range of tree crops (and sometimes other vegetation) is divided for classification or use

aggradation: (from Bormann and Likens, 1979. Pattern and process in a forested ecosystem.) in Northern Hardwoods, a period of more than a century when the ecosystem accumulates total biomass reaching a peak at the end of the phase; preceded by the reorganization phase and followed by the transition phase

advance regeneration: in silvicultural terms, young trees that have become established naturally in a forest, in advance of regeneration cutting; may become established following "preparatory" cuts

allogenesis: changes in an ecological community primarily through periodic, acute, external (exogenous) disturbances, such as storms. These changes generally reset the successional progression of the community.

area inch; acre inch: used to describe changes in water yield from a given area of land; for instance, if a change in vegetation results in an increase of one acre inch in water yield, this translates to 43,560 x 1/12 = 3630 cubic feet per acre, = 3630 / 7.5 = 484 gallons additional yield per acre, area inch is simply translated to percentage of water yield increase by dividing area inch by total inches of yield, for example a watershed may get 40 inches of precipitation of which 20 inches is runoff - a 2 area inch increase in yield = 2/20 = 10% increase

autogenesis: changes in an ecological community primarily through the regular, internal processes of growth, competition, and senescence, which are general endogenous (within community) forces that result in a steady successional progression of the community.

basin; sub-basin: the land area from which all water flows to a single, identified water source, such as a stream, a river, or a reservoir. Sub-basin is used to refer to the basin of a tributary, or lower *order* stream (the higher the order, the greater the area drained).

basal area: the area in square feet of the cross section of a tree taken at 4.5 feet above the ground

"beaver pipe"; flow control pipe: generally a length of culvert that is extended into a beaver pond and at or near the top of the beaver dam, in order to maintain the pond level at a particular level.

Best Management Practices, BMP's: in natural resources management, refers to a set of standards that have been designed for an activity, and often a region, to protect against degradation of resources during management operations.

biological diversity (or "biodiversity"): a measure, often difficult to quantify, of the variety and abundance of plant and animal species within a specified area, at the genetic, species, and landscape level of analysis. The 1992 UN Convention on Biological Diversity defined biodiversity as "the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems"

biomass: (SAF) the total quantity, at a given time, of living organisms of one or more species per unit area (species biomass) or of all the species in a community (community biomass)

Block: the largest administrative unit imposed on the Quabbin; the approximately 58,000 acres of MDC properties have been divided into 5 "Blocks"; Pelham, New Salem, Prescott, Petersham, and Hardwick. Note that "Blocks" are currently being reorganized into major sub-drainages of the Quabbin watershed

Compartment: administrative subunits of the Blocks described above, generally 200-400 acres in size, delineated by features such as roads, walls, forest type changes, water bodies

conservation restriction; conservation easement: a legal agreement between a landowner and another party whereby the landowner deeds the rights to development of the property to the other party, but retains ownership of the land and other rights to its use. Specific agreement varies, but the general result is to protect land from conversion to new uses without requiring transfer of ownership; MDC also limits or retains the right to approve certain agricultural and silvicultural practices in its cr's

Continuous Forest Inventory (C.F.I.): an extensive method of forest inventory in which permanent sample plots are remeasured at periodic intervals to determine forest growth and condition; MDC's CFI is composed of 1/5 acre permanent plots, located on a 1/2 mile grid, and remeasured every 10 years

cutting cycle: the frequency with which silvicultural cuttings are conducted in any given area; cutting cycle is a subunit of "rotation", which is determined either by the maximum life of the existing overstory, or by a predetermined maximum age imposed on the area

Cryptosporidium: A coccidian protozoan parasite found in humans and various wild and domestic animals that can be transmitted via water and often causes serious intestinal illness. While the epidemiology and transmission of Cryptosporidium are similar to Giardia, its oocysts are smaller that the cysts of other protozoa, and thus may be more difficult to remove from water supplies.

diameter at breast height; DBH: the diameter of a tree, outside the bark, taken at 4.5' above the ground, generally in inches and fractions

diverse/diversity: in this plan, the term is most often used to refer to forest composition, and refers to both height or size diversity in trees, seeking a minimum of three distinct layers (understory, midstory, and overstory), and to diversity of species composition, with a general goal of avoiding monocultures and working to include components of hemlock, pine, oak, birch, and maple throughout the forest

disturbance-sheltered: areas that are physically (based on slope and aspect) "sheltered" from the influence of a catastrophic New England hurricane blowing from the southeast, based on a model developed at the Harvard Forest; the most sheltered areas are steep slopes facing northwest.

edge effect: traditionally, this term has been used to describe the increased richness of flora and fauna found where two habitat types or communities meet. More recently, the term has also been used to refer to the increased predation and brood parasitism that often occurs near these boundaries.

endogenous disturbance: disturbance that originates within the ecological community. For example, a single tree that succumbs to a root-rot fungus and falls to the ground, breaking off several other trees on the way, creates an endogenous disturbance. While the proximal cause of the treefall may be wind or accumulation of snow and ice, the primary cause is still considered endogenous in this instance. (see exogenous disturbance below)

even-aged: (SAF) an area of forest composed of trees having no, or relatively small, differences in age. NOTE: By convention the maximum difference admissible is generally 10 to 20 years, though with rotations of 100 years or more, differences up to 30% of the rotation may be admissible.

exogenous disturbance: disturbance that originates from forces outside of the ecological community. For example, storms that carry high winds can cause large-scale treefall well in advance of normal senescence and decay. The cause of the disturbance is therefore considered exogenous. (see endogenous disturbance above)

feller-buncher; feller-buncher-processor: logging machines that grasp a tree to be cut or "felled", sever it at the stump with either a saw or hydraulic shears, and directionally drop it to the ground. Some machines can accumulate, or "bunch" several trees before releasing them. The most complex machines are also capable of delimbing and sawing trees into predetermined lengths (processing).

forest canopy: (SAF) the more or less continuous cover of branches and foliage formed collectively by the crowns of adjacent trees and other woody growth.

forest fragmentation: the separation of a previously contiguous forested area into discontinuous patches or "fragments". These fragments are less useful to wildlife that require large contiguous habitats. Fragmentation by suburban development is likely to be detrimental to "deep woods" species, while the simple break imposed by an access road is not often an impediment.

forwarder: a logging machine used to "forward" logs from the woods to a landing. Differs from a skidder in that the logs are hydraulically loaded onto the machine and carried, rather than skidded through the woods.

G.I.S.: Geographic Information System - a computer-based analysis and mapping system for spatially-linked data sets

Giardia: A protozoan parasite found in humans and various wild and domestic animals that can be transmitted via water and often causes serious intestinal illness.

hurricane exposure ("exposed", "intermediate", "sheltered"): generally used in MDC management plans to mean physical exposure of a site to catastrophic hurricane winds, those coming from the southeast. Research at the Harvard Forest in Petersham, MA provides a model of the impact of this typical New England hurricane, which includes slope and aspect. Actual damage will depend on the type and size of vegetation present.

intermediate cut: cutting of trees in a stand during the period between establishment and maturity. Objectives may include the improvement of vigor by reducing competition or the manipulation of species composition. Regeneration may occur following intermediate cuts, but it is incidental to the objectives.

irregular shelterwood: similar to the shelterwood silvicultural system except that overstory removals are protracted, taking as long as half the rotation, so that the resulting new stand is quite uneven-aged (wide intervals between the oldest and youngest trees) and mimics the multi-storied effect of strictly uneven-aged systems

log landing; landing: a clearing of variable size to which logs, pulp, and/or firewood are skidded or forwarded during a logging operation, in order to facilitate their processing or further transport by truck.

mast: the fruit and seeds of trees and shrubs. Mast constitutes an important food source for many wildlife species.

milacre: one one-thousandth of an acre as in "milacre plots for regeneration inventory"

mineral soil: any soil consisting primarily of minerals (sand, silt, and clay) material, rather than organic matter

multi-storied or multi-layered forest: a forest containing a distinct understory, midstory, and overstory. From a watershed perspective, these layers provide, respectively, immediate response to disturbance, vigorous uptake of nutrients, and deep filtration of air-borne and precipitative pollutants

"naturally managed": the results of a deliberate decision to allow natural disturbances and processes prevail by adopting a minimal management approach that protects forests from development or other land use changes and possibly human-caused fire, but which includes vegetation management only where it clearly counteracts a negative result from previous human disturbances

Off-Reservation: MDC-controlled lands within the Quabbin watershed that are outside the major highways surrounding the reservoir

old-growth: various definitions, but one definition in Massachusetts is that old-growth must contain at least four acres in which the dominant trees are late-successional species, have reached at least half the potential maximum age of the species with a few trees at or near that age (e.g. birches/maples at 300 years or hemlocks at 400), have late-successional tree regeneration present, and show little or no evidence of human or large-scale natural disturbance during the current stand's development

preparatory cutting: (SAF) removing trees near the end of a rotation so as to open the canopy and enlarge the crowns of seed bearers, with a view to improving conditions for seed production and the establishment of natural regeneration

protected: refers to areas of the watershed that, according to the Harvard Forest model of hurricane disturbance, would suffer minimal damage from the recurrence of a hurricane similar to that of 1938, due primarily to topography and orientation

protection forest: (SAF) an area, wholly or partly covered with woody growth, managed primarily to regulate stream flow, maintain water quality, minimize erosion, stabilize drifting sand, or to exert any other beneficial forest influences

Quabbin watershed system: MDC-controlled lands within, and adjacent to, the Quabbin watershed (includes both Reservation and Off-Reservation lands)

regeneration: recently established tree growth, generally smaller than one inch dbh; also, the process of establishing this growth, as in "bring about the regeneration of a forest area"

regeneration cut: (SAF) any removal of trees intended to assist regeneration already present or to make regeneration possible

Reservation: MDC-controlled lands that fall within the major highways surrounding Quabbin Reservoir. This land area is subject to stricter MDC regulation than off-Reservation lands, including the prohibition of general public hunting.

riparian: pertaining to the bank of a stream or other water body; (SAF) vegetation growing in close proximity to a watercourse, lake, swamp, or spring, and often dependent on its roots reaching the water table

rotation: in conventional forestry, rotation is (SAF) the planned number of years between the formation or regeneration of a crop or stand and its final cutting at a specified stage of maturity. In the selection system of uneven-aged management, however, the concept of a rotation is replaced with the average age of trees removed to initiate regeneration

salvage; salvage cutting: the removal of trees damaged by fire, wind, insects, disease, fungi, or other injurious agents before their timber becomes worthless. In some situations, the motivation is the reduction of fuel loading and fire hazard. Sanitation cutting is related, but is a proactive removal of diseased or highly susceptible trees in order to slow or halt the spread of a disease or other destructive agent.

seep: a wet area, generally associated with groundwater seepage, which is important to wildlife because it remains unfrozen, and generally uncovered, during periods when the ground is otherwise snow-covered, which makes it easier for wildlife to forage for seeds

shelterwood: (SAF) mostly even-aged silvicultural systems in which, in order to provide a source of seed, protection for regeneration, or a specific light regime, the overstory (the shelterwood) is removed in two or more successive shelterwood cuttings, the first of which is ordinarily the seed cutting (though it may be preceded by a preparatory cutting) and the last of which is the final cutting, while any intervening cuttings are termed removal cuttings. Note that where adequate regeneration is already present, the overstory may be removed in one cutting, resulting in a method referred to as a one-cut shelterwood.

silviculture: (SAF) generally, the science and art of cultivating (i.e. growing and tending) forest crops, based on a knowledge of silvics (the study of the life history and general characteristics of forest trees and stands, with particular reference to environmental factors affecting growth and change). More particularly, the theory and practice of controlling the establishment, composition, constitution, and growth of forests.

site: in forestry, the combination of environmental factors that affect the ability of a species to grow and persist, including at least soil characteristics, aspect, altitude and latitude, and local climate. Sites are often classified by the ability of specific trees to grow on them.

site index: the ability of a given site to grow a given species. As height growth is generally not density dependent, a common forestry site index is the height to which a given species will grow on the site in fifty years (so that a site with a Red Oak site index of 65 will grow Red Oak to that height in fifty years).

site preparation: in silviculture, any of a variety of treatments of a site that are intended to enhance regeneration success. A common goal of these treatments is to remove enough of the accumulated organic layers above the mineral soil so as to expose that soil and enhance the ability of seeds that fall on it to germinate and grow. The simple skidding of logs is an incidental, and often sufficient site preparation.

site-suited: species that have evolved to take advantage of a particular type of site. Where species are planted on other sites, they may succumb prematurely to disturbance or disease. Red pine grows and persists well on deep, sandy soils, where root rots are less common, but may become excessively prone to wind and or root rotting diseases on the moist agricultural soils on which they were typically planted.

skidder: logging machine used to "skid" logs from the woods to a landing or a forwarder road. Logs are either winched by cable to the skidder (cable skidder), or lifted on one end by a hydraulic grapple (grapple skidder), and then dragged.

stand: (SAF) a community of trees possessing sufficient uniformity as regards composition, constitution, age, spatial arrangement, or condition to be distinguishable from adjacent communities.

steady state: (Bormann and Likens, 1979. p.4) "For the ecosystem as a whole, over a reasonable period of time gross primary production equals total ecosystem respiration, and there is no net change in total standing crop of living and dead biomass"

stocking: in forestry, the extent to which a site is occupied by trees compared to the maximum occupation possible at a given stand age; a relative measure of stand density. Most commonly measured as basal area per acre, stocking is often related directly to crown closure, as a site is considered fully occupied when crown closure is complete (when each crown has grown to touch all adjacent ones). As crowns can be of very different sizes among species and tree ages within stands, average diameter (dbh) and total number of trees of a "fully stocked" site is variable.

stream order: a classification of streams within watersheds. Small streams at the uppermost level of stream systems are labeled "first-order"; two first-order streams join to form a "second-order" stream; two second-order streams join to form a "third-order" stream; etc.

succession: (SAF) the gradual supplanting of one community of plants by another, the sequence of communities being termed a "sere" and each stage "seral". Succession is "primary" (by "pioneer species") on sites that have not previously borne vegetation, "secondary" after the whole or part of the original vegetation has been supplanted; it is "allogenic" when the causes of succession are external to and independent of the community (e.g. a storm, or climate change), and "autogenic" when the developing vegetation is itself the cause. "Early succession" generally refers to the pioneer stages and species that follow disturbance, while "late succession" refers to stages and species that occur as an area continues to develop undisturbed for long periods.

thinning: an intermediate silvicultural treatment, generally with the goal of altering the forest composition and/or improving the growing conditions for the residual trees, regardless of associated regeneration effects. Most thinnings leave stands considered to be fully stocked, i.e. capable of fully occupying the site a short while after the thinning has been completed.

turbidity: a water quality measure that is most commonly derived by measuring the proportion of a given amount of light that is deflected by suspended/dissolved sediments in a water sample, giving an indirect measure of these sediments. Most common unit is the Nephalometric Turbidity Unit, NTU.

uneven-aged: (SAF) a forest, crop, or stand composed of intermingling trees that differ markedly in age. By convention, a minimum difference between tree ages of 25% of the rotation age is generally accepted. Some texts require a minimum of three distinct age classes for a stand to qualify as "uneven-aged".

vernal pool: a temporary body of fresh water that provides crucial habitat for several vertebrate and many invertebrate species of wildlife, but does not support fish populations.

wetland: generally refers in the MDC land management plans to areas defined as "wetlands" by M.G.L. C.131 § 40 (the "Wetlands Protection Act") and 310 C.M.R. 10.00 (the "Wetlands Protection Regulations"), updated as these are revised.